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NAKO GESUNDHEITS-STUDIE

# MANUAL ON THE AVAILABILITY AND PROPOSED UTILIZATION OF PHYSICAL ACTIVITY DATA IN THE GERMAN NATIONAL COHORT (NAKO)

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Authors in alphabetical order: Hansjörg Baurecht, Julian Brummer, Christoph Buck, Sylvia Gastell, Florian Herbolsheimer, Lilian Krist, Michael Leitzmann, Michael Stein, Karen Steindorf, Andrea Weber

*NAKO Expert Group Fitness, Physical Activity*

Bundesministerium für Forschung, Technologie und Raumfahrt

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## Abbreviations

| | |
|---|---|
| PA | Physical Activity |
| NAKO | German National Cohort |
| GPAQ | Global Physical Activity Questionnaire |
| QUAP | Questionnaire on Annual Physical Activity Pattern |
| cpar24 | Computer-based 24-hour Physical Activity Recall |
| MET | Metabolic equivalent |
| ENMO | Euclidean Norm Minus One |
| MAD | Mean Amplitude Deviation |
| LTPA | Leisure time PA |
| MPA | Moderate PA |
| MVPA | Moderate-to-vigorous PA |
| VPA | Vigorous physical activity |
| WHO | World Health Organization |

# 1 Summary

The report “Multimodal Assessment of Physical Activity in the German National Cohort (NAKO)” by the "Expert Group Physical Activity and Fitness" aims to provide an overview of the central physical activity assessment methods used in the NAKO-Gesudheitsstudie (NAKO). Please study these recommendations carefully if you intend to work with physical activity as a primary outcome or exposure.

If you only plan to adjust for physical activity, we recommend using the General Physical Activity Questionnaire (GPAQ; Variables: a_gpaq_ptotal and a_gpaq_ptotalmet).

For <u>subsamples</u> of the accelerometry (ActiGraph, Variables: akdys_mad), the Questionnaire on Annual Physical Activity Pattern (QUAP; Variables: a_quap_patotal, a_quap_mettotal), or the Computer-Based 24-Hour Physical Activity Recall (cpar24; Variables: a_cpar_act_metmin_f)

The expert group members are delighted to help you with any inquiry and assist you with the variable selection. We aim to publish consistent results across all NAKO publications focusing on physical activity.

## 2 Background: Multimodal Assessment of Physical Activity

There are various methods available for assessing physical activity (PA), but there is no universally accepted "gold standard" for measuring it. Each method has its own specific strengths and limitations. To address these challenges, the NAKO adopted a multimodal approch that combines self-report and device-based methods to obtain comprehensive information and compensate for limitations. Specifically, PA is assessed using two self-administered questionnaires: The Global Physical Activity Questionnaire (GPAQ) and the Questionnaire on Annual Physical Activity Pattern (QUAP). Additionally, a computer-based recall protocol ("computer-based 24-hour physical activity recall" [cpar24]) was utilized, along with hip-worn accelerometry using the ActiGraph GT3X/+.

The PA assessments cover different periods ranging from recalling habitual PA of the past 12 months to measuring the upcoming 7 days after visiting the study center (Figure 1).

Moreover, the four instruments cover different domains of PA, as detailed in Table 1.

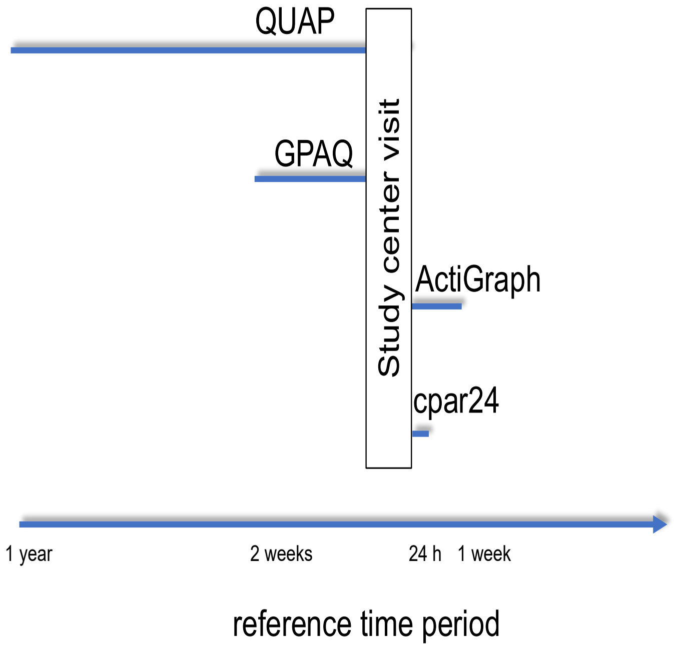



***Figure 1.*** Reference periods assessed with the four PA instruments

***Table 1.*** Physical activity domains

| Domain | GPAQ | QUAP | cpar24 | Accelerometry |
|---|---|---|---|---|
| Work | x | (x) | x | Measure of PA volume without contextual or domain-specific information |
| Household | | x | x | |
| Transport (walking, cycling) | x | x | x | |
| Leisure PA | x | x | x | |
| Sports/exercise | | x | x | |
| Sedentary time | x | x | x | |
| derived and quality-assured number of observations | 184,000 | 60,000 | 47,600 | 63,000 |

### Quality management of the data

The following recommendations are based on extensive internal and external consultations. Members of the expert group have implemented most of the measures for PA themselves, cleaned the raw data, and provided derived variables. In general, all PA measures underwent a through data-cleaning process, which included several assumptions and cross-data checks. Data cleaning is crucial during the processing stage and often requires a trade-off between a larger sample size and ensuring accuracy in measurements.

> Researchers are advised to apply the decisions made during the cleaning process and utilize the derived variables.
>
> Of course, researchers can determine their own criteria for what constitutes a valid data set, whether that be more lenient or strict. In essence, each researcher can establish quality criteria and calculate variables based on those standards. The interpretation of the results concerning the data quality is at the discretion of the analyzing researcher.

This manual outlines the first version of best practices for selecting and using PA data in the NAKO. More sound recommendations will be provided after the expert group has received actual NAKO data. For authorship regulations, please refer to the NAKO publication guidelines.

Currently, the expert working group on PA recommends using PA data in the NAKO study as follows:

### Central outcome or exposure

If PA is the central outcome or exposure, it is recommended that the expert group be contacted. In general, the researchers should bear in mind that different instruments for the assessment of PA are used in the NAKO surveys and that these instruments measure various aspects of PA in different sub-cohorts:

The GPAQ assesses self-reported PA during leisure time, for transport, and at work, as well as sedentary behavior. The QUAP assesses habitual PA, focusing on seasonal PA patterns. Contextual information of specific days is assessed using the time use instrument cpar24. Objectively measured PA is assessed device-based via 7-day accelerometry (ActiGraph – GT3X/GT3X+).

**Covariate**

If PA is used as a covariate, it is currently advisable to use the GPAQ, which is applied to the whole cohort. However, the GPAQ is subject to certain limitations, which need to be considered (see below, section 4.1).

# 3 Device-based assessment: Accelerometry

In past and upcoming surveys, the NAKO has used a triaxial accelerometer, the ActiGraph GT3X/+ (ActiGraph, Pensacola, FL, USA). ActiGraph's ActiLife version 6.11.0 is used to initialize the devices at a frequency of 100 Hz, an epoch length of 10 seconds, and the filter setting "normal". Participants wear the accelerometer for seven days above the right hip. Therefore, PA is measured continuously and during the night. A non-wear diary is not used. In the NAKO, accelerometry is intended for at least 40% of all participants in the baseline examination (n=80,000). The follow-up surveys aim to get as many participants as possible to take part.

## 3.1 What are ".gt3x "and ".agd "files?

The devices record triaxial acceleration at 100 Hz (raw data), which is exported as a .gt3x file. Furthermore, the specific algorithms of ActiGraph's ActiLife software (Version 6.11.0) are used to calculate "total activity counts". These manufacturer-derived data are exported as .agd files. When applying for accelerometry data, researchers can choose between:

1) Unverified raw data (.gt3x or .agd not recommended by the expert group)
2) Quality-assessed data derived from raw data (in the following named: .gt3x)
3) Or manufacturer-derived data (in the following named: .agd).

## 3.2 What is a valid data point?

### 3.2.1 Raw data

Data cleaning is needed during the processing phase before utilizing PA variables derived from raw or manufacturer-derived count-based datasets. To ensure that processed variables from the gt3x files are ready for immediate use, the expert group decided that two-thirds of a full day (16 hours) of valid accelerometry data, i.e., excluding the detected non-wear time, was included for further data processing. This decision aligns with recent discussions in the current body of accelerometry studies

(Migueles u. a. 2019; Weber u. a. 2024). Researchers who process the raw data have the flexibility to choose different cut-offs or algorithms to be either more restrictive or inclusive. More details on these steps are given in section 3.2.3

A valid week was defined by considering raw accelerometry measurements starting the day following the visit to the study center and continuing for seven complete days. Data collected on the initial day previous midnight and any recordings after the eighth day were excluded from analysis (see Figure 2). For analysis, we recommend including only participants with data from at least one valid weekend day, a minimum of two valid weekdays, and a full 24-hour cycle. Missing values were imputed only for 15-minute time frames classified as non-wear time by taking the average of matching time points on other recording days of the same person.

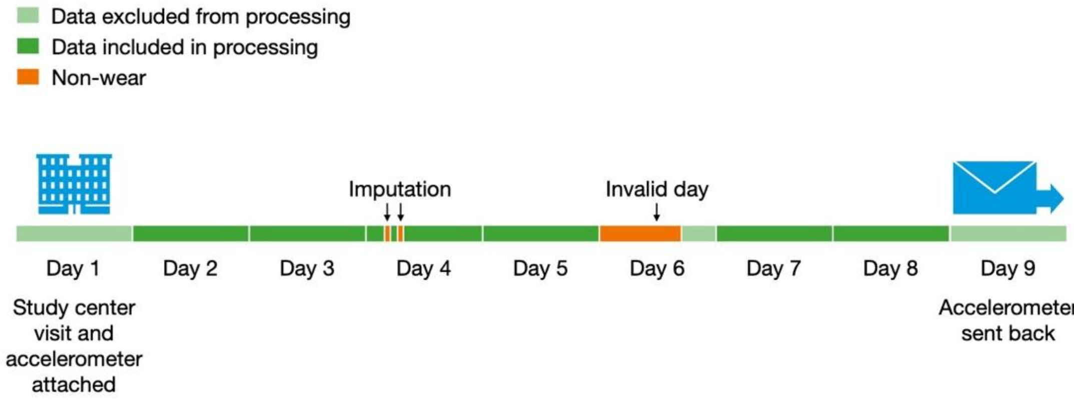



***Figure 2.*** Reference periods assessed with the four PA instruments

### 3.2.2 .agd data

To obtain an initial overview of the completeness (24/7) of the acceleration measurements carried out, the .agd data is subjected to strict quality control. A key feature of this first step in determining a valid data set is that the device must be worn for at least 23 hours a day.

Of course, depending on the research question, researchers can define less stringent criteria for a valid data set. For example, manufacturer-derived variables can also be requested if the devices were worn for less than 7 days over 23 hours/day. For example, the days on which the device was only worn for 16 or 10 hours. In principle, researchers can define quality criteria and calculate variables accordingly. The interpretation of the results with regard to the quality of the data is at the discretion of the analyzing researcher.

No imputations have yet been made for the .agd data.

### 3.2.3 .gt3x data: Basic concepts of processing of raw accelerometry data

This section briefly describes the different steps of processing the raw accelerometry data with the R package GGIR. Further information can be found in the GitHub repository and in the corresponding publications:

- Weber A, van Hees VT, Stein MJ. et al. Large-scale assessment of physical activity in a population using high-resolution hip-worn accelerometry: the German National Cohort (NAKO). Sci Rep 14, 7927 (2024). https://doi.org/10.1038/s41598-024-58461-5
- Migueles JH, Rowlands AV, Huber F, Sabia S, van Hees VT. GGIR: A Research Community–Driven Open Source R Package for Generating Physical Activity and Sleep Outcomes From Multi-Day Raw Accelerometer Data. Journal for the Measurement of Physical Behaviour. 2019;2(3):188-96.
- GitHub repository of NAKO processing pipeline: https://github.com/UREpiPrevMed/nako-accelerometry
-

The consecutive data processing steps are:

1. Auto- or g-calibration
   Automatic detection of non-movement periods and derivation of correction factors for calibrating each sensor axis
2. Non-wear detection
   Classify a period as non-wear time if, within a given time window, both of the following criteria are met on at least two out of the three accelerometer axes: (1) standard deviation of acceleration values fall below brand-specific reference thresholds, and (2) the range between maximum and minimum acceleration values is less than 50 m*g*
3. Signal clipping
   If more than 50% of the data values within a time window are close to the maximal dynamic range of the sensor, then data are considered invalid.
4. Collapse data at epoch level
   Data are aggregated at epoch level, as there is little evidence that raw data accurately represent body acceleration. Aggregating at this level may also help average out varying noise levels, enhancing comparability across sensor brands.

Different data sets with different resolutions can be applied through the established NAKO routines for data access.

- On a person level, aggregated physical activity across the whole week
- On a day level, physical activity per day (only valid days as defined above)
- Physical activity time series will be provided in 15-minute aggregated intervals across all days, resulting in 96 data points (4 per hour over 24 hours) per participant.

To enable high-quality analyses, it is recommended to exclude participants with low data quality, e.g., high (>0.02) or missing calibration error, high signal clipping (>0.1), and insufficient amount of valid days (see below, 3.4.2). For this purpose, flag variables (flag_exclusion, flag_insuffWT) can be accessed. Moreover, outliers at the 99.9$^{th}$ age- and sex-specific percentiles should be winsorized.

#### *3.2.3.1 Raw data-based measures (ENMO and MAD)*

Established variables, which can be interpreted as acceleration volume, were derived.

Studies have shown that the Euclidean Norm across the three-movement axes correlates sub-optimally with energy expenditure. Therefore, the Euclidean Norm Minus One (**ENMO**) was developed, and calculated by subtracting one gravitational unit from the Euclidean Norm. Negative values are set to zero, and the resulting value is converted from *g* to m*g*. Finally, the average per epoch is computed. It is essential to ensure correct G-calibration, as this is critical for reliable ENMO values. ENMO is a well-established metric, particularly suited for wrist-worn accelerometers.

Alternatively, the Mean Amplitude Deviation (**MAD**) was calculated by subtracting the Euclidean Norm from the 5-second average Euclidean Norm at each time point. The absolute value is then converted from *g* to m*g,* and the average per epoch is determined. Notably, calibration error has a lesser impact on MAD measurements.

Both metrics correlate well with energy expenditure and yield similar results. While ENMO is more commonly used, MAD may offer advantages for hip-worn accelerometers due to its lower sensitivity to calibration errors. However, unlike ENMO, MAD relies on assumptions about gravitational acceleration at frequencies below 0.2 Hz.

The expert group emphasizes that neither measure is considered superior, as both are widely utilized in recent literature. However, to guide researchers, we generally recommend using MAD.

#### *3.2.3.2 Intensity-based measures (MVPA)*

The guidelines on moderate-to-vigorous physical activity (MVPA) are based on a mixture of inconsistent methods. Also, MVPA does not perfectly capture variation in energy expenditure, and acceleration does not necessarily correlate with the intensity of MET-based activity. In accelerometry, MVPA is estimated using a threshold-based approach, which interprets it as the duration of time spent with a certain amount of body movement. Thresholds have been derived from small studies and may not be applicable across different age groups. Consequently, the concept of MVPA is suboptimal. However, given its frequent use in research, we derived a wide range of estimates. This includes thresholds for both ENMO and MAD, spanning from 20 to 430 mg with varying epoch lengths from 5 seconds to 5 minutes and different bout algorithms. These estimates offer a variety of options for primary and sensitivity analyses in future studies.

While the expert group recommends metrics such as MAD or ENMO, researchers may opt for MVPA estimates using a 1-minute epoch length without a bout criterion if the research question necessitates it. In such cases, a MAD threshold of 90m*g*, or an ENMO threshold of 70m*g* can serve as a useful starting point (Hildebrand u. a. 2014; Vähä-Ypyä u. a. 2015).

Authors working with MVPA should be aware that the 2020 WHO guidelines have removed the previous requirement of 10-minute activity bouts, as specified in the 2010 WHO guidelines. As a result, the percentage of individuals classified as sufficiently physically active has changed. Under the 2010 guidelines, 33.5% of NAKO participants (using MAD) and 23.3% (using ENMO) would have been considered to meet the activity requirements. However, with the removal of the bout duration criterion and the inclusion of MVPA bouts of any length, the proportion of individuals meeting the guidelines has significantly increased, now reaching **94.3**% (MAD) and **78.3**% (ENMO).

It is strongly advised to acknowledge the limitations associated with threshold-based metrics and to explore various thresholds and parameters during sensitivity analyses. All combinations of epoch length/ bout criteria/ thresholds should be considered.

## 3.3 Processing of.agd data

ActiGraph's ActiLife version 6.11.0 is used to initialize the devices at a frequency of 100 Hz, an epoch length of 10 seconds, and the filter setting "normal". To enable high-quality analyses, it is recommended to exclude participants who have less than 7 days of at least 23 valid hours each day or for whom the technical default settings (frequency, epoch length, filter) were not correct.

### 3.3.1 .agd data measures

The main output of ActiGraph's software is referred to as "counts", which is generated from the original raw acceleration signal recorded across three axes. From this data, "Total Vector Magnitude Counts" can be calculated. This Vector Magnitude combines all three axes using the vector magnitude formula. When analyzing epoch-level data (post-filtered and accumulated), the vector magnitude is defined as VM = $\sqrt{(Axis1)^2 + (Axis2)^2 + (Axis3)^2}$. This value represents "Total Activity Counts" across all three axes over a 7-day period.

### 3.3.2 Intensity-based measures

Using cut points, users can analyze the proportion of time participants spent in the various activity intensity categories within each data set. The cut point algorithm employed in the NAKO was "Adult VM3 (Freedson)".

The cut points for the activity levels are: Light ≤ 2490, Moderate 2491-5944, Vigorous ≥ 5945, and Moderate-to-Vigorous (MVPA) ≥ 2491.

## 3.4 Cheat Sheets for Using NAKO accelerometry data

ActiGraph accelerometers were worn continuously above the right hip for a full 7 days, recording triaxial acceleration. Only quality-checked data with a minimum of 16 hours of wear time per day were included in the analysis.

### 3.4.1 Cheat Sheet: ActiLife-generated counts data (.agd)

The ActiLife software version 6.11.0 is used to generate count data. The cut point algorithm "Adult VM3 (Freedson)" is used to determine the activity levels.

**Study sample:** High-quality data sets comprising 7 valid days of data were collected from approx. 42,000 participants, nearly 20% of whom were level 2 participants.

**When to use counts:** Relevant when comparing data with other studies that also collected "Total Activity Counts"  over a 7-day period.

**Important derived variables (see also data dictionary):**

| *Person level* | |
|---|---|
| Light | Number of minutes spent on light activity (≤ 2490 counts per minute) |
| Moderate | Number of minutes spent on moderate activity (2491-5944 counts per minute) |
| Moderate-to-vigorous | Number of minutes spent on moderate to vigorous activity (≥ 2491 counts per minute) |
| Vigorous | Number of minutes spent on vigorous activity (≥ 5945 counts per minute) |
| Bouts_moderate | Sustained periods of elevated counts to identify exercise times in moderate activity. ActiLife provides details on the duration of these bouts. allowing for a maximum interruption tolerance of 2 minutes. |
| Steps | Number of steps |
| Sum_wt_days | Number of days on which the device was worn for a total of at least 23 hours. |

**Exclusion of participants**

| | |
|---|---|
| flag_exclusion_count == 1 | quality/technical issues: The participant should be excluded from analyses |
| flag_insuffWT_count == 1 | participant has less than 7 days (23 hours valid) of data |

**Characteristics:** Data records on the intensity and total time spent in physical activity over a period of 7 days.

**Limitations:** While ActiGraph activity counts have been widely used in the field, there are concerns regarding their replicability with other monitors and a lack of transparency in the data processing methods. The manufacturer does not provide detailed hardware and software information about the device.

**Strengths:** device-based physical activity measures; large samples and an objective standardized way of measuring the data

There is a high number of calibration and validation studies available that deal with the output of ActiGraph's "Counts"

**References:**

Brønd, JC; Andersen, LB; Arvidsson, D. Generating ActiGraph Counts from Raw Acceleration Recorded by an Alternative Monitor. Med. Sci. Sports Exerc. 2017, 49, 2351-2360.

Neishabouri, A; Jguyen, J; Samuelsson, J; Guthrie, T; Biggs, M; Wyatt, J; Cross, D; Karas, M; Migueles, J; Khan, S; Guo, C. Quantification of acceleration as activity counts in ActiGraph wearable. Scientific Reports. 2022, 12:11958.

Sasaki, JE; Dinesh, J; Freedson, PS. Validation and comparison of ActiGraph activity monitors. J. Sci. Med. Sport. 2011, 14, 411-416.

### 3.4.2 Cheat Sheet: Raw accelerometry data-derived variables (.gt3x)

The R package GGIR version 2.10-3 was used to process the raw data and to derive summary metrics.

**Study sample at baseline:** accelerometry was intended for at least 40% of all participants (n=80,000); high-quality data is available of approx. 63,000 participants.

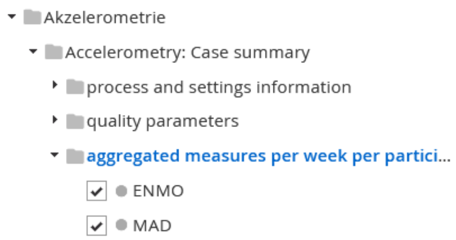
**When to use variables derived from raw accelerometry data:** These device-based physical activity metrics offer high-resolution insights without the need for processing the raw data again

**Exclusion of participants**

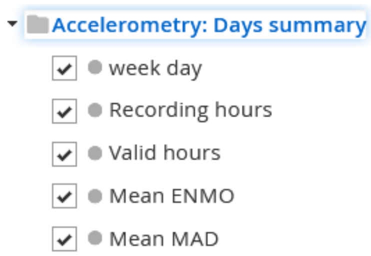
| | |
|---|---|
| aksum_invalid == 1 | quality/technical issues: Participants should be excluded from analyses |
| aksum_insuffwt == 1 | participant has insufficient wear time (N.valid.WEdays < 1 \| N.valid.WKdays < 2 \|complete_24hcycle != 1) and should be excluded |

**Important derived variables (see also data dictionary):**

| *Person level* | |
|---|---|
| Variable name and selection in NAKO TransferHub | Variable description |
| aksum_enmo | Average ENMO across all days in m*g* |
| aksum_mad | Average MAD across all days in m*g* |




| *Day level* | |
|---|---|
| akdys_enmo | Average ENMO per day in m*g* |
| akdys_mad | Average MAD per day in m*g* |




| *15-minute time series (average of all measured days)* | |
|---|---|
| akts_enmo | Average ENMOs per 15-minute interval averaged from all days in m*g* |
| akts_mad | Average MADs per 15-minute interval averaged from all days in m*g* |

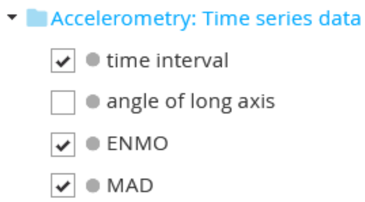



***Figure 3.*** MVPA-section in the NAKO-TransferHub

**Applying for MVPA (moderate to vigorous physical activity)**

To represent time spent at different levels of physical activity intensity (measured by acceleration), various estimates were derived based on various time intervals, acceleration thresholds, and duration criteria. This provides a range of options for data analysis and sensitivity analyses.

One option is to use a 1-minute time interval without detecting activity bouts. Depending on the research question, researchers should refer to the relevant threshold values in the literature (see References below).

Due to the absence of a clear, measurable definition for moderate-to-vigorous physical activity (MVPA) and the fact that acceleration does not consistently correlate with MET-based activity intensities, we recommend using the **ENMO and MAD** values for a **1-minute time interval without bout** detection, with thresholds of **70 mg and 90 mg**, respectively, as starting points. Other combinations of time intervals, bout detection, and thresholds are also applicable.

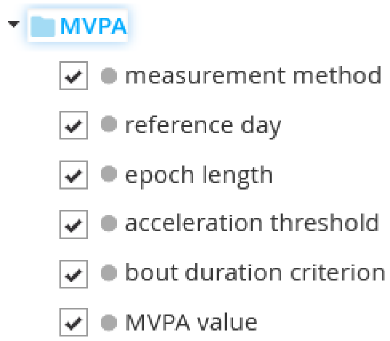



***Figure 4.*** MVPA-section in the NAKO-TransferHub

All variables must be selected in the TransferHub and specified in more detail in the section "Neue Population hinzufügen (Add new population)", e.g.,

| | |
|---|---|
| akdet_method == 2 AND | (MAD (Mean Amplitude Deviation)) |
| akdet_time == 20 AND | (Average over all available days) |
| akdet_epoch == 60 AND | (1-minute time interval) |
| akdet_bout == 0 | (without bout) |

**Characteristics:** Various data sets are available, each offering different levels of detail: person level, day level, and 15-minute level (aggregated across all days)

Winsorize outliers at the age- and sex-specific 99.9$^{th}$ percentile

**Limitations:** There is currently no information available on sedentary behavior. MVPA variables should be used with caution, as those estimated using ENMO and MAD thresholds are not directly comparable; the thresholds were derived from different studies.

**Strengths:** device-based PA measures; large sample and plausible values

**References:**

Weber A, van Hees VT, Stein MJ. et al. Large-scale assessment of physical activity in a population using high-resolution hip-worn accelerometry: the German National Cohort (NAKO). Sci Rep 14, 7927 (2024). https://doi.org/10.1038/s41598-024-58461-5

Migueles JH, Rowlands AV, Huber F, Sabia S, van Hees VT. GGIR: A Research Community–Driven Open Source R Package for Generating Physical Activity and Sleep Outcomes From Multi-Day Raw Accelerometer Data. Journal for the Measurement of Physical Behaviour. 2019;2(3):188-96.

Overview of published LPA, MPA, VPA cutpoints: https://cran.r-project.org/web/packages/GGIR/vignettes/CutPoints.html#3_Summary_of_published_cut-points

https://github.com/UREpiPrevMed/nako-accelerometry

# 4 Physical activity questionnaires

## 4.1 Global Physical Activity Questionnaire (GPAQ)

The GPAQ was developed by the World Health Organization and is widely used in research. It consists of 16 questions on the occurrence, frequency, and duration of occupational, transport-related, and leisure time MVPA as well as sedentary behavior. In NAKO, the self-administered version of the GPAQ was used in the touchscreen examination. The GPAQ Analysis Guide was used to ensure data quality and derive variables.

**Study sample:** all NAKO participants; high completeness rate; valid data of approx. 184,000 participants.

**When to use GPAQ:** large sample, simple measure of physical activity; adjustment variable

**Important derived variables (see also data dictionary):**

| | |
|---|---|
| ptotal | Total physical activity; minutes per week |
| ptotalmet | MET-Minutes per week total physical activity |
| p16 | Minutes per day in sedentary behaviour |
| percent_rec. | Proportion (%) of leisure time physical activity in total physical activity |

**Exclusion of participants**

| | |
|---|---|
| cln == 2 (nein) | Exclude; physical activity domains implausible according to Analysis Guide |
| p16cln == 2 (nein) | Exclude; SB implausible according to Analysis Guide |

**Characteristics:** No longer used in the second follow-up examination (2024)

Participants with > 10080 min/week of physical activity ➔ winsorize!

**Limitations:** very high physical activity levels reported, with 90% of participants meeting the WHO recommendations (150 minutes/week moderate PA OR 75 minutes/week vigorous PA), particularly among older individuals

➔ discuss critically in manuscripts

➔ focus on relative differences instead of absolute physical activity levels

➔ use percentiles instead of global cut-off values

**Strengths:** high completeness

**References:**

World Health Organization (WHO). Global Physical Activity Questionnaire (GPAQ) Analysis Guide. Surveillance and Population-Based Prevention. Prevention of Noncommunicable Diseases Department. 20 Avenue Appia. 1211 Geneva 27. Switzerland. (www.who.int/chp/steps).

## 4.2 Questionnaire of Annual Physical Activity Patterns (QUAP)

Prof. Steindorf's Division at the German Cancer Research Center (DKFZ) developed the QUAP, a self-administered questionnaire consisting of 22 items about physical activity undertaken in the past 12 months. It is organized into 6 sections that assess various domains: occupation, household, transport, leisure time physical activity, sports and exercise, and sedentary behavior. The questionnaire collects information on the type, frequency, duration, and perceived intensity of activities, with intensity levels categorized as light, moderate, or somewhat heavy. The QUAP was adapted for use in NAKO, where participants complete the self-administered paper version at home and send it to the study centers.

**Study sample**: Valid data of approx. 60,000 participants at baseline

**When to use the QUAP**: Focus on habitual physical activity in contexts where seasonal variations are relevant or sports activities play an important role.

**Important derived variables (see also data dictionary):**

| | Variable | Specification (in min/day; MET/h) |
|---|---|---|
| **Housework** | a_quap_hausarbeit | Housework |
| **Transport** | a_quap_fortbew_so | Transport in summer |
| | a_quap_fortbew_wi | Transport in Winter |
| **Leisure** | a_quap_spazier_so | Walking in Summer |
| | a_quap_spazier_wi | Walking in Winter |
| | a_quap_radtour_so | Cycling in Summer |
| | a_quap_radtour_wi | Cycling in Winter |
| **Sports** | a_quap_sport_frue | Sports activities in Spring |
| | a_quap_sport_somm | Sports activities in Summer |
| | a_quap_sport_herb | Sports activities in Autumn |
| | a_quap_sport_wint | Sports activities in Winter |
| | a_quap_sport_comb | The sum of sports activities |
| **Total activity score** | a_quap_patotal | The sum of physical activities |
| **Sedentary time** | a_quap_seed_week | Average sedentary time during the week |
| | a_quap_seed_sa | Sedentary time on Saturday |
| | a_quap_seed_so | Sedentary time on Sunday |

**Exclusion of participants:** Missing consent

**Characteristics:** Each participant should have at least one assessment, either at baseline or at the first follow-up assessment. MET value variables are available for every measure. The QUAP will be adapted and implemented across the entire cohort in the 2nd Follow-up, replacing the GPAQ.

**Limitations:** Only available for a subsample; potential recall biases

**Strengths:** Comprehensive information on various physical activity domains across different seasons, as well as detailed information about sports activities.

### References:

Brühmann, B. A., Schmidt, M. E., Wientzek, A., Vigl, M., Teucher, B., Katzke, V. A., Boeing, H., Bergmann, M. M., Kaaks, R., & Steindorf, K. (2014). Reliability and validity of the Questionnaire on Annual Physical Activity Pattern: A validation study using combined heart rate and accelerometry data as an objective measurement. World J Epidemiol Cancer Prev, 3(7).

## 4.3 computer-based 24-hour physical activity recall (cpar24)

The cpar24 is a computer-based time-use instrument specifically developed for NAKO. Participants recorded their activities from the previous day (typically the day following their visit to the study center) in intervals of at least 5 minutes. They selected from a list of 262 individual activities (see also the CSV list) and, in some cases, specified their position and intensity. Manual entries were also permitted.

**Study sample:** Includes all participants with either an accelerometer or Somnowatch (sensor for sleep detection), particularly **w**hen contextual physical activity or time use is of importance

**Important derived variables (see also data dictionary):**

| | |
|---|---|
| a_pk_final | Primary key of activities (for linkage to csv. Activity list) |
| a_activityname_final | Activity name |
| a_oberkat_final | Activity category |
| a_durkorr | Duration of activity (minutes) after cleaning of data |
| a_metmin_final | MET-minutes of activity (MET values see compendium by Ainsworth) after cleaning of data |
| a_intkat | Intensity category of activity |

**Exclusion of participants**

| | |
|---|---|
| a_flag_vollst == 0 (nein) | Exclude, ≤ 3 activity entries and not equal to 1440 minutes per day |
| a_flag_invalidtime == 1 (ja) | Exclude, multiple overlapping activities, days with changes to daylight saving time. |
| a_flag_zeitraum_plaus %in% c(3,4) | Cpar24 login is not plausible (e.g., it occurs before the study center visit). To link with accelerometer data, the variable a_flag_zeitraum_plaus == 2 should also be excluded |

**Characteristics:**

Each participant has multiple rows (one for each activity)

No cpar24 assessment in the first follow-up examination (2019-2024)

Linkage to accelerometry data: a_flag_zeitraum_plaus == 1 participants filled out the cpar24 during the accelerometer wear period. Linkage through the day of the week or via central data management.

**Limitations:**

Only one day of data per participant at baseline; information bias

**Strengths:**

Contextual information; less prone to recall and social desirability bias than traditional questionnaires.

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