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How a 10-minute bout requirement for physical activity affects guideline adherence estimates, Germany

Julian Brummer,[a] Michael J Stein,[b] Hansjörg Baurecht,[b] Mirko Brandes,[c] Christoph Buck,[c] Antje Hebestreit,[c] Lilian Krist,[d] Michael Leitzmann,[b] Andrea Weber,[b] Volker Harth,[e] Jana-Kristin Heise,[f] Verena Katzke,[g] Thomas Keil,[d] Alexander Kluttig,[h] Claudia Meinke-Franze,[i] Rafael Mikolajczyk,[h] Ute Mons,[j] Katharina Nimptsch,[k] Nadia Obi,[e] Cara Övermöhle,[l] Annette Peters,[m] Tobias Pischon,[k] Börge Schmidt,[n] Matthias B Schulze,[o] Henry Völzke,[i] Stefan N Willich,[d] Florian Herbolsheimer[a] & Karen Steindorf[a]

[a] Division of Physical Activity, Cancer Prevention and Survivorship, German Cancer Research Center, Im Neuenheimer Feld 581, Heidelberg, 69120, Germany.

[b] Department of Epidemiology and Preventive Medicine, University of Regensburg, Regensburg, Germany.

[c] Leibniz Institute for Prevention Research and Epidemiology, Bremen, Germany.

[d] Institute of Social Medicine, Epidemiology and Health Economics, Charité – University Medical Center Berlin, Berlin, Germany.

[e] Institute for Occupational and Maritime Medicine, University Medical Center Hamburg-Eppendorf, Hamburg, Germany.

[f] Department of Epidemiology, Helmholtz Centre for Infection Research, Braunschweig, Germany.

g Division of Cancer Epidemiology, German Cancer Research Center, Heidelberg, Germany.

[h] Institute for Medical Epidemiology, Biometrics, and Informatics, Medical Faculty of the Martin Luther University Halle-Wittenberg, Halle, Germany.

[i] Institute for Community Medicine, University Medicine Greifswald, Greifswald, Germany.

[j] Division of Primary Cancer Prevention, German Cancer Research Center, Heidelberg, Germany.

[k] Molecular Epidemiology Research Group, Max Delbrück Center for Molecular Medicine in the Helmholtz Association, Berlin, Germany.

[l] Institute of Epidemiology, Kiel University, Kiel, Germany.

[m] Institute of Epidemiology, Helmholtz Zentrum München – German Research Center for Environmental Health (GmbH), Neuherberg, Germany.

[n] Institute for Medical Informatics, Biometry and Epidemiology, University Hospital of Essen, Essen, Germany.

[o] Department of Molecular Epidemiology, German Institute of Human Nutrition Potsdam-Rehbruecke, Nuthetal, Germany.

Correspondence to Karen Steindorf (email: k.steindorf@dkfz-heidelberg.de).

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Abstract

Objective To examine how adherence to the World Health Organization's (WHO) physical activity guidelines changes with and without the application of a 10-minute bout requirement.

Methods We analysed accelerometry data from the baseline assessment of the German National Cohort, NAKO. Using predefined acceleration thresholds, we classified each participant's volumes of moderate and vigorous intensity physical activity and compared these values with WHO guidelines. We analysed data with and without the 10-minute bout requirement. We used Welch's analysis of variance and equal proportions tests to compare demographic and health characteristics between participants who met the activity guidelines and those who did not.

Findings Of 63 134 participants, 22 226 (35.2%) met the guidelines with the bout requirement, while 62 532 (99.0%) met the guidelines without it. Participants who met the guidelines under each condition differed in demographic and health-related characteristics. For example, mean age was 48.6 years (SD: 13.0) among participants meeting the bouted guidelines, 50.8 years (SD: 12.2) among those meeting only the non-bouted guidelines and 60.8 years (SD: 10.4) among those meeting neither guidelines. Participants meeting the bouted guidelines had a lower body mass index (25.2 kg/m^2; SD: 4.0) than those meeting only the non-bouted guidelines (27.0 kg/m^2; SD: 5.1) and those meeting neither guidelines (30.6 kg/m^2; SD: 7.1)

Conclusion Removing the 10-minute bout requirement for accelerometry-measured activity volumes substantially increased estimated guideline adherence. The change has implications for interpreting time trends in guideline adherence and alters conclusions about which population subgroups meet the guidelines.

Introduction

Physical activity provides many health benefits.[1,2] Consequently, health authorities worldwide have established physical activity guidelines[1–6] which serve as a foundation for public health strategies.[1] In 2020, the World Health Organization (WHO) published revised physical activity guidelines.[1,4] The revised guidelines continue to recommend a minimum of 150 minutes moderate intensity aerobic physical activity, 75 minutes of vigorous intensity aerobic physical activity or an equivalent combination of both per week.[1] An important change, however, was the removal of the requirement that only activity bouts of at least 10 minutes could count towards the weekly goal (henceforth referred to as the bout requirement).[1] Within the broader evolution of physical activity guidelines in recent decades,[7,8] the bout requirement became increasingly obsolete as device-based measurements of physical activity gained prominence. This shift coincided with evidence supporting the health benefits of physical activity of any duration, which could be assessed without relying solely on participants' self-reports.[9,10] The implications of the change to the bout requirement on guideline adherence remain unclear.

The broader definition of guideline-relevant physical activity means that, irrespective of actual changes in population physical activity, more individuals are now likely to be classified as adhering to the guidelines. Few studies address this issue and those that do use varying methodologies and report inconsistent findings. Several accelerometry-based studies observed that removing the 10-minute bout requirement substantially increased adherence to moderate and vigorous physical activity guidelines.[11–13] For example, a nationally representative Canadian study reported that removing the 10-minute bout requirement increased guideline adherence from 18.5% to 45.3%,[11] while a smaller-scale Japanese study found an even greater increase from 12.5% to 92.4%.[12] In contrast, two self-report-based studies found only marginal changes when removing the bout requirement.[14,15] These differences in adherence after removing the bout requirement may affect subgroups of the population differently,[11,12] which could have important implications for targeted physical activity promotion.

This study aimed to determine how accelerometry-measured adherence to the WHO aerobic physical activity guidelines changes with and without the application of the 10-minute bout requirement. We also aimed to examine the demographic and health-related characteristics of participants meeting the guideline under both conditions.

Methods

The reporting of this study follows the STROBE guidelines.[16]

Study setting

We used data from the baseline examination of the German National Cohort (NAKO) study, conducted between 2014 and 2019.[17] NAKO is an ongoing multidisciplinary, multicentre, population-based prospective cohort study, whose framework, design, and methods have previously been described in detail.[17–19] The NAKO study used random age- and sex-stratified sampling from compulsory population registries in 16 study regions, comprising 18 study centres across Germany. At baseline, the study included 205 414 participants from 1 316 055 million randomly selected eligible residents, marking a response proportion of 15.6%.[19] Participants were aged 19–74 years at baseline.[17] All relevant ethics committees approved the study before onset. The NAKO study follows the Declaration of Helsinki and all participants provided written informed consent. All study data can be applied for and obtained via the NAKO electronic application portal.[20]

Physical activity assessment

A subsample from the NAKO baseline examination took part in seven-day, triaxial, hip-worn, 100Hz accelerometry using ActiGraph (Pensacola, United States of America) devices to measure physical movement.[21] The NAKO study sampling strategy for this subsample of its multilevel data collection is described in detail elsewhere.[17] In brief, accelerometry was assigned to 50% of participants undergoing only the basic examination programme (74 222 out of 148 444 participants).[17] However, some study centres exceeded that proportion, resulting in 89 949 out of the 205 414 participants being offered accelerometry.[17] As participation in the accelerometry module was voluntary, not all assigned participants took part and the data set we received from the NAKO team contained accelerometry data from 72 713 participants.

The evolution of ActiGraph product line during the NAKO baseline examination necessitated the use of three ActiGraph models (GT3X+, wGT3X+, and wGT3X-BT).20 NAKO study personnel attached the ActiGraph devices to participants during the study centre visit, placing them above the right hip on the mid-axillary line using an elastic strap, wearable over or underneath clothing.[21] The NAKO team asked participants to conduct their usual activities and remove the ActiGraph devices only during prolonged (more than 30 minutes) water exposure. Based on the methodological recommendations of the NAKO Expert Group on Physical Activity and Fitness, we considered days to be valid if the device recorded at least 16 valid hours per day. With the advice of the expert group, we evaluated the validity of any single measurement day before examining whether the required number of weekdays and weekend days was available and excluded participants with less than one valid weekend day or fewer than two valid weekdays. Additionally, we excluded participants with an incomplete 24-hour cycle (participants with consistently invalid data for any given 15-minute interval across all recording days) to ensure full representation of the 24-hour cycle. The quality control measures and data processing of the raw accelerometry data have been described in detail elsewhere.[21] Briefly, we primarily processed the data using GGIR (Version 2.10–3) an open-source R package;[22] we excluded recordings with calibration errors exceeding 0.02 units of gravitational acceleration, detected and imputed non-wear time, and derived summary metrics for physical activity.[21]

We used the mean amplitude deviation to quantify time spent at different physical activity intensities.[21] By applying established acceleration thresholds[23] we calculated each participant's weekly duration of moderate and vigorous intensity physical activity. In our primary analyses we applied thresholds at 90 milligravity for moderate and 410 milligravity for vigorous intensity activity (where 1 g ≈9.81 m/s2). For sensitivity analyses, we also applied lower and higher thresholds:[21] 80 milligravity and 100 milligravity for moderate and 400 milligravity and 420 milligravity for vigorous intensity activity. We aggregated the raw data over a time interval of five seconds, equating to an epoch length of five seconds. To derive the weekly volumes of moderate and vigorous intensity activity, we multiplied the average daily values by seven. We winsorized outliers at the 99.9th percentile within each age and sex group to address possible calibration issues or sensor malfunctions[21] because some extreme values persisted despite rigorous exclusion criteria.

We dichotomized adherence to the WHO physical activity guidelines, categorizing participants as adherent or non-adherent based on the following criteria: (i) at least 150 minutes per week of moderate intensity activity; (ii) at least 75 minutes per week of vigorous intensity activity; or (iii) an equivalent combination of moderate and vigorous intensity activity, calculated as minutes per week of moderate intensity plus two times minutes per week of vigorous intensity totalling at least 150 minutes per week.

We assessed guideline adherence in two ways: (i) the bouted approach[11], applying the 10-minute bout requirement, following the previous WHO guidelines[24] and requiring at least 80% of epochs to meet the threshold criteria; and (ii) the non-bouted approach, removing the 10-minute bout requirement, consistent with the current WHO guidelines.[1]

We extended previous work[11] by categorizing participants into three mutually exclusive groups: (i) adherents, who met the previous bouted guidelines and therefore also met the current non-bouted guidelines; (ii) transitioners, who met only the non-bouted guidelines; and (iii) non-adherents, who did not meet either set of guidelines.

Statistical analysis

We computed descriptive statistics, including means and standard deviations (SD). We used paired t-tests to compare volumes of moderate and vigorous intensity physical activity. To compare adherents, transitioners and non-adherents by age, body mass index (BMI), self-reported overall health (scale from one to five, from poor to excellent) and activity volumes, we applied Welch's analysis of variance followed by Games–Howell post hoc tests. We chose these procedures because Levene's tests indicated that the assumption of homogeneity of variance was violated for all variables of interest (P-values: < 0.001). To compare the three groups by sex and highest educational attainment, we used tests of equal proportions (prop.test function in R) and pairwise comparisons for proportions, with Bonferroni correction (pairwise.prop.test function in R). For educational level, we used the 2011 International Standard Classification of Education to classify participants as having low (primary and lower secondary education), medium (upper secondary and post-secondary non-tertiary education) or high (bachelor's level or equivalent and above).[25] Where indicated, we report P-values and 95% confidence intervals (CI) to evaluate statistical significance.

We used R version 4.4.1,[26] in RStudio version 2024.04.2, (Posit Software, PBC, Boston, USA) to conduct all statistical analyses.

Results

The analysis included data from 63 134 participants (Fig. 1). The sample had a relatively balanced sex distribution. The mean age of participants was 50.1 years (SD: 12.6; range: 19.0–74.0), with a mean BMI of 26.4 kg/m2 (SD: 4.8; range: 14.4–62.2) and they reported relatively good overall health with a mean score of 3.3 points (SD: 0.7; range: 1–5; Table 1).

Guideline adherence

Among participants, 35.2% (22 226) were adherents who met the bouted guideline, an additional 63.8% (40 306) of participants qualified as transitioners, which together resulted in 99.0% (62 532) meeting the non-bouted guideline. Only 1.0% (602) of participants were in the non-adherents category, not meeting either guideline.

The sensitivity analyses using ± 10 milligravity as the acceleration thresholds for classifying moderate and vigorous intensity activity showed that, for non-bouted activity, 98.3%

(62 065) met the guideline at the higher thresholds and 99.5% (62 835) at the lower thresholds. For the bouted activity, 31.7% (20 045) met the guideline at the higher thresholds and 39.5% (24 934) at the lower thresholds.

Physical activity volumes

Weekly volumes of both moderate and vigorous activity were considerably higher when non-bouted activity was included than when only bouted activity was considered (Table 2). Under both non-bouted and the bouted conditions, participants accumulated substantially more moderate activity than vigorous activity.

Activity volumes were highest among adherents, intermediate among transitioners and lowest among non-adherents under both bouted and non-bouted definitions. Fig. 2 and Fig. 3 visualizes the respective moderate and vigorous activity volumes, respectively.

Associated factors

The demographic and health-related characteristics differed across adherents, transitioners and non-adherents (Table 1). Analysis of variance with post-hoc pairwise comparisons yielded statistically significant results (all P-values: < 0.001) showing that adherents were younger, had the lowest BMI, and reported the better overall health than the other two groups. The differences were most pronounced in the comparisons between adherents and non-adherents: On average, the adherents were 12.1 years (95% CI: 11.1–13.2) younger, their BMI was 5.5 kg/m2 (95% CI: 4.8–6.1) lower, and their self-reported overall health was 0.8 points (95% CI: 0.8–0.9) higher. Transitioners were located in between the adherents and the non-adherents for all three measures. Compared with adherents, transitioners were on average 2.1 years (95% CI: 1.9–2.4) older, had a BMI 1.9 kg/m2 (95% CI: 1.8–1.9) higher and reported overall health scores 0.2 points (95% CI: 0.2–0.2) lower. Compared with the non-adherents, transitioners were 10.0 years (95% CI: 9.0–11.0) younger, had a BMI that was 3.6 kg/m2 (95% CI: 2.9–4.3) lower and their self-reported overall health was 0.6 points (95% CI: 0.5–0.7) higher.

The tests of equal proportions revealed statistically significant differences in the sex and education composition of the groups (Table 1). The post-hoc tests showed several statistically significant pairwise comparisons. There was a greater proportion of females among the transitioners than among the adherents and the non-adherents (all P-values: < 0.001). While, among the adherents and the transitioners, there was a higher proportion of participants with high versus medium education, whereas among the non-adherents, there was a greater proportion of participants with medium versus high education (all P-values: < 0.001).

Discussion

Based on accelerometry data in a large population-based sample from Germany, our study found that removing the 10-minute bout requirement nearly tripled adherence to WHO aerobic physical activity guidelines. Further, there were systematic differences in demographic and health-related characteristics among participants meeting the guidelines when the 10-minute bout requirement was removed rather than applied.

The finding that guideline adherence was notably higher when using non-bouted activity is consistent with previous studies examining the impact of the bout requirement on accelerometry-measured guideline adherence.[11–13] The findings appear plausible, as the removal of the bout requirement considerably broadens the range of physical activity that counts towards guideline adherence. Physical activity that is now considered guideline-relevant includes brief forms of exercise and non-exercise activities. Brief forms of physical exercise, such as high-intensity interval training, have well documented health benefits, including reducing adiposity and increasing cardiorespiratory fitness.[27,28] A growing body of evidence also indicates that short bursts of exercise and intermittent physical activity can promote health.[29,30]

It is important to acknowledge that removing the 10-minute bout requirement hampers the analysis of time trends in moderate and vigorous physical activity guideline adherence. Increases in adherence are partly due to changes in the guidelines rather than actual increases in physical activity. Therefore, accelerometry-based studies examining guideline adherence should report both bouted and non-bouted results to enable comparisons with previous studies.

Our study also identified clear differences in the demographic, health and physical activity characteristics among individuals meeting the moderate and vigorous physical activity guidelines. Overall, we observed a gradient: those meeting the bouted guideline were the youngest, had the lowest BMI, reported the best health and accumulated the most moderate and vigorous physical activity. Differences by sex and education were also evident. Taken together, and contrary to a previous accelerometry study,[11] we found that the revised guidelines for non-bouted activity seem to capture a different demographic than the bouted guidelines, although it should be noted that almost all participants were classified as adhering to the non-bouted activity guideline. The small subset of the sample that still did not meet the broader guidelines may represent an important target for public health interventions. Interestingly, despite this small subset of participants not meeting the non-bouted guidelines, around 10% of the total sample (6224/61 704 with data on self-reported overall health) reported less-than-good or poor overall health. This finding suggests that the non-bouted guideline targets might be so low that individuals with health impairments can still meet them.

Several lessons emerge from our study. First, the revisions to the 2020 WHO guidelines relied on self-reported physical activity data, which may not translate well to accelerometry-derived metrics due to discrepancies between measures.[31] Future guidelines should incorporate more evidence from accelerometry-based assessments.[10,32,33] Notably, almost all participants met the guideline when the 10-minute bout requirement was removed, raising questions about whether most individuals genuinely achieve sufficient moderate and vigorous physical activity levels or if the thresholds need to be reconsidered. Second, methodological choices in accelerometry research, such as epoch length, substantially influence activity estimates. Short epochs capture brief, sporadic movements prompting questions of whether higher activity thresholds may be necessary or the use of longer epochs for comparability with existing evidence. Harmonization efforts are needed to address processing differences while maintaining clarity and usability for the general population.

A strength of our study is the use of a large, population-based sample, aiding subgroup analysis and the use of accelerometry to overcome self-report bias. Accelerometry may be particularly valuable for assessing non-bouted activity by helping to overcome individuals' recall issues, such as forgetting brief and irregular bursts of activity. However, our approach also has limitations. The sampling strategy may have introduced bias due to differences between study centres and self-selection bias of participants willing to engage in the accelerometry module. Similarly, the baseline data of the NAKO study, collected between 2014 and 2019, may not fully reflect current activity patterns in Germany given the widespread use of device-based self-monitoring of activity. Further, accelerometry analysis involves certain limitations related to computational approaches. We required participants to have valid data for at least two weekdays and one weekend day to better represent weekly activity, considering the typical differences in activity patterns between weekdays and weekends.[34,35] Our method averaged data across available days and extrapolated to a full week, implicitly assuming that the observed days are representative of the entire period. Further potential concerns pertain to differences in results due to analysis choices[36,37] or the generalizability of thresholds derived from smaller studies.[21]

We have documented our analytical approach to facilitate future evaluations and replication. Our sensitivity analyses using several acceleration thresholds yielded consistent results but limitations like reactivity bias, where participants may move more due to wearing the accelerometer, cannot be completely ruled out.

In conclusions, our study found that applying the revised guidelines to accelerometry data substantially changes estimates of population adherence and the characteristics of those classified as meeting the guidelines. The findings have important implications for the interpretation of time trends in physical activity guideline adherence, the identification of which population subgroups are meeting or are not meeting the guidelines and methodological considerations for analysing accelerometry data for guideline development.

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FH and KS contributed equally and share last authorship. JB is also affiliated with the Medical Faculty, Heidelberg University, Heidelberg, Germany. TK is also affiliated with the Institute of Clinical Epidemiology and Biometry, University of Würzburg, Würzburg, Germany, and the State Institute of Health, Bavarian Health and Food Safety Authority, Erlangen, Germany. UM is also affiliated with the Medical Faculty Mannheim, Heidelberg University, Mannheim, Germany. AM is also affiliated with the Chair of Epidemiology, Institute for Medical Information Processing, Biometry and Epidemiology, Medical Faculty, Ludwig-Maximilians-Universität München, Munich, Germany. TP is also affiliated with the Max-Delbrueck-Center for Molecular Medicine in the Helmholtz Association, Biobank Technology Platform, Berlin, Germany, and the Charité – Universitätsmedizin Berlin, corporate member of Freie Universität Berlin and Humboldt-Universität zu Berlin, Berlin, Germany. MBS is also affiliated with the Institute of Nutritional Science, University of Potsdam, Nuthetal, Germany. We thank all participants who took part in the NAKO study and the staff of this research initiative. We also thank Vincent T van Hees (Accelting, Almere, Kingdom of the Netherlands) and Hansjörg Baurecht (University of Regensburg, Regensburg, Germany).[21]

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Competing interests:

None declared.

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Table 1. **Participant characteristics in the study on the 10-minute bout requirement for physical activity guideline adherence, Germany, 2014–2019**

Characteristic	Total sample (*n* = 63 134)	Adherents (*n* = 22 226)	Transitioners (*n* = 40 306)	Non-adherents (*n* = 602)	*P* for group difference[a]
Sex, no. (%)					< 0.001
Male	30 210 (47.9)	11 082 (49.9)	18 796 (46.6)	332 (55.1)	
Female	32 924 (52.1)	11 144 (50.1)	21 510 (53.4)	270 (44.9)	
Age in years, no. (%)					NA
19–29	5 678 (9.0)	2 681 (12.1)	2 980 (7.4)	17 (2.8)	
30–39	6 535 (10.4)	2 439 (11.0)	4 080 (10.1)	16 (2.7)	
40–49	16 533 (26.2)	5 933 (26.7)	10 566 (26.2)	34 (5.6)	
50–59	17 184 (27.2)	5 897 (26.5)	11 165 (27.7)	122 (20.3)	
60–69	15 895 (25.2)	4 885 (22.0)	10 663 (26.5)	347 (57.6)	
≥ 70	1 309 (2.1)	391 (1.8)	852 (2.1)	66 (11.0)	
Age in years, mean (SD)	50.1 (12.6)	48.6 (13.0)	50.8 (12.2)	60.8 (10.4)	< 0.001
Education level, no. (%)[b]					< 0.001
Low	1 553 (2.5)	365 (1.7)	1 142 (2.9)	46 (7.7)	
Medium	25 096 (40.6)	7 402 (34.4)	17 376 (43.8)	318 (53.4)	
High	35 152 (56.9)	13 775 (63.9)	21 145 (53.3)	232 (38.9)	
BMI categories, no. (%)[c]					NA
Underweight	674 (1.1)	268 (1.2)	399 (1.0)	7 (1.2)	
Normal weight	26 567 (42.1)	11 484 (51.7)	14 953 (37.1)	130 (21.6)	
Overweight	23 454 (37.2)	7 971 (35.9)	15 310 (38.0)	173 (28.7)	
Obese, class I	8 816 (14.0)	2 021 (9.1)	6 651 (16.5)	144 (23.9)	
Obese, class II	2 611 (4.1)	388 (1.7)	2 135 (5.3)	88 (14.6)	
Obese, class III	994 (1.6)	87 (0.4)	847 (2.1)	60 (10.0)	
BMI in kg/m2, mean (SD)	26.4 (4.8)	25.2 (4.0)	27.0 (5.1)	30.6 (7.1)	< 0.001
Self-reported overall health, no. (%)					NA
Poor	459 (0.7)	94 (0.4)	324 (0.8)	41 (7.3)	
Less good	5 765 (9.3)	1 346 (6.2)	4 221 (10.7)	198 (35.1)	
Good	34 065 (55.2)	10 700 (49.1)	23 083 (58.6)	282 (50.0)	
Very good	19 066 (30.9)	8 387 (38.5)	10 642 (27.0)	37 (6.6)	
Excellent	2 349 (3.8)	1 246 (5.7)	1 097 (2.8)	6 (1.1)	
Self-reported overall health score, mean (SD)	3.3 (0.7)	3.4 (0.7)	3.2 (0.7)	2.6 (0.8)	< 0.001

BMI: body mass index; NA: not applicable; SD: standard deviation.

[a] Refers to differences among the three groups: Adherents, transitioners and non-adherents

[b] Classified using the International Standard Classification of Education 2011 level24 and categorized as low (primary and lower secondary education), medium (upper secondary and post-secondary, non-tertiary education) or high (bachelor's or equivalent level and above).

[c] We used the following BMI cut-offs (kg/m2): underweight: BMI < 18.5; normal weight: BMI ≥ 18.5 and < 25.0; overweight: BMI ≥ 25.0 and < 30.0; class I obese: BMI ≥ 30.0 and < 35.0; class II obese: BMI ≥ 35.0 and < 40.0; class III obese: BMI ≥ 40.0.

Notes: adherents are those who met the bouted physical activity guideline (participants in this group automatically also met the non-bouted physical activity guideline); transitioners are those who did not meet the bouted guideline but met the non-bouted guideline. Non-adherents are those who did not meet the non-bouted guideline and therefore met neither guideline. Due to missing data, the number of participants in the variables education level, BMI and self-reported overall health does not equal the total sample size reported for each column.

Table 2. **Participant weekly activity levels in the study on the 10-minute bout requirement for physical activity guideline adherence, Germany, 2014–2019**

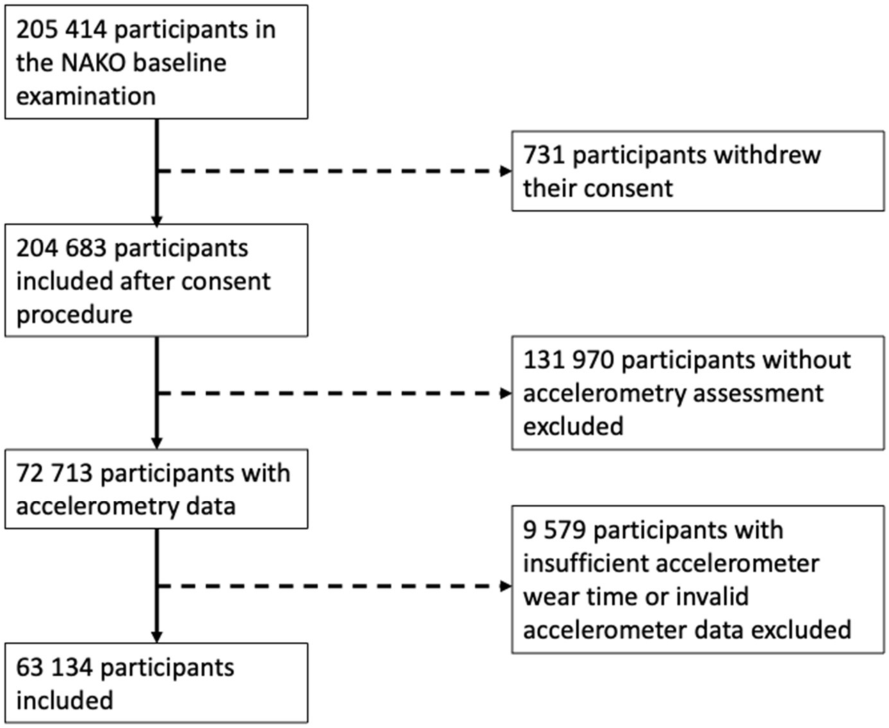
Intensity of physical activity	Mean minutes per week (SD)				*P* for group difference[a]
	Total sample (*n* = 63 134)	Adherents (*n* = 22 226)	Transitioners (*n* = 40 306)	Non-adherents (*n* = 602)	
Bouted					
Moderate	123.5 (133.3)	256.4 (140.3)	52.0 (43.9)	6.6 (15.1)	< 0.001
Vigorous	9.4 (32.6)	24.6 (50.9)	1.1 (6.0)	0.1 (1.0)	< 0.001
Moderate and vigorous	132.9 (141.3)	280.9 (138.9)	53.1 (44.1)	6.7 (15.2)	NA
Non-bouted					
Moderate	565.9 (216.4)	695.5 (205.4)	501.2 (183.0)	108.5 (34.3)	< 0.001
Vigorous	18.5 (39.3)	40.0 (57.9)	6.9 (13.2)	0.3 (1.7)	< 0.001
Moderate and vigorous	584.3 (226.6)	735.5 (209.0)	508.1 (185.9)	108.8 (34.2)	NA

NA: not applicable; SD: standard deviation.

[a] Refers to differences among the three groups: adherents, transitioners and non-adherents.

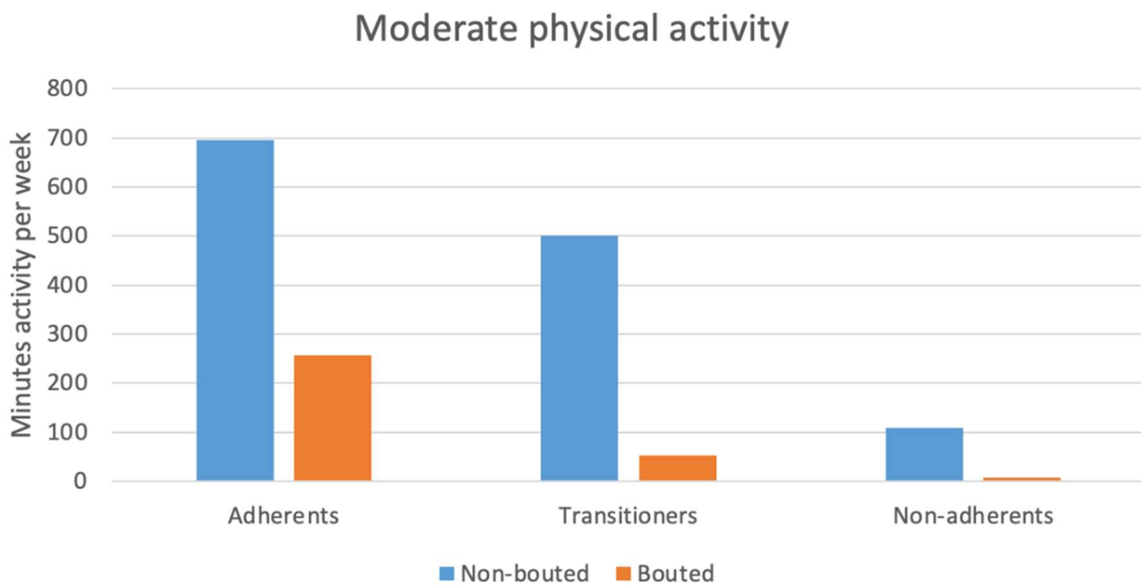
Notes: adherents are those who met the bouted physical activity guideline (participants in this group automatically also met the non-bouted physical activity guideline); transitioners are those who did not meet the bouted guideline but met the non-bouted guideline. Non-adherents are those who did not meet the non-bouted guideline and therefore met neither guideline. Moderate and vigorous physical activity was calculated by summing moderate and physical activity. Note that means and standard deviations are reported to facilitate comparability and interpretability, despite right-skewness in several variables.

Fig. 1. **Participant flow in the study on the 10-minute bout requirement for physical activity guideline adherence, Germany, 2014–2019**



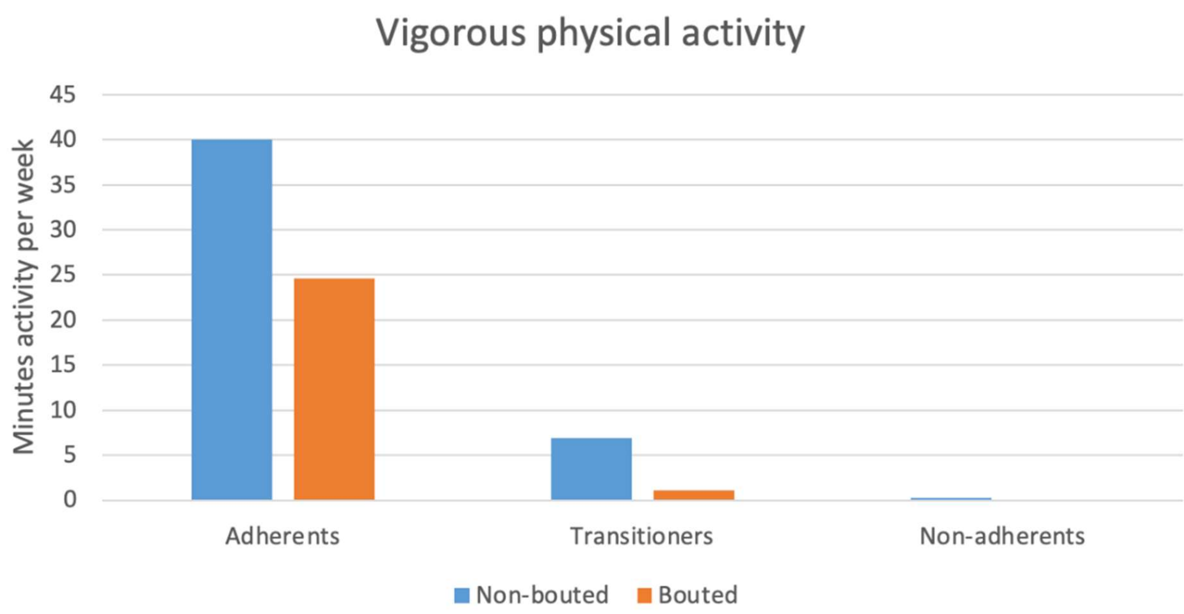
NAKO: German National Cohort.

Fig. 2. **Mean weekly volumes of moderate physical activity in the study on the 10-minute bout requirement for physical activity guideline adherence, Germany, 2014–2019**



Note: acceleration thresholds used were 90 milligravity for moderate physical activity. All group differences and pairwise comparisons reached statistical significance (*P*-values: < 0.001).

Fig. 3. **Mean weekly volumes of vigorous physical activity in the study on the 10-minute bout requirement for physical activity guideline adherence, Germany, 2014–2019**



Note: acceleration thresholds used were 410 milligravity for vigorous physical activity. All group differences and pairwise comparisons reached statistical significance (*P*-values: < 0.001).