Differences in accelerometer measured patterns of physical activity and sleep/rest between ethnic groups and age: an analysis of UK Biobank

Physical activity and sleep/rest differences between ethnic groups and age

Original research

Nathan P. Dawkins, MSc[1,2] (ORCID: 0000-0002-6374-7908) nd177@leicester.ac.uk, Tom Yates, PhD[1,2] (ORICD: 0000-0002-5724-5178) ty20@leicester.ac.uk, Cameron Razieh, MSc[1,2] (ORCID: 0000-0003-3597-2945) cr288@leicester.ac.uk, Charlotte L. Edwardson, PhD[1,2] (ORICD: 0000-0001-6485-9330) ce95@leicester.ac.uk, Ben Maylor, PhD [1,2] (ORICD: 0000-0002-4503-0479) bm259@leicester.ac.uk, Francesco Zaccardi, PhD[1,3] (ORCID: 0000-0002-2636-6487) fz43@leicester.ac.uk, Kamlesh Khunti, MD [1,4] (ORICD: 0000-0003-2343-7099) kk22@leicester.ac.uk, Alex V. Rowlands, PhD [1,2,5] (ORCID: 0000-0002-1463-697X) alex.rowlands@leicester.ac.uk.

1. Diabetes Research Centre, University of Leicester, Leicester General Hospital, Leicester, UK
2. NIHR Leicester Biomedical Research Centre, UK
3. Leicester Real World Evidence Unit, Leicester Diabetes Centre, Leicester General Hospital, Leicester, UK
4. NIHR Applied Research Collaboration East Midlands, Leicester General Hospital, UK
5. Alliance for Research in Exercise, Nutrition and Activity (ARENA), Sansom Institute for Health Research, Division of Health Sciences, University of South Australia, Adelaide, Australia

Abstract word count: 200

Main text word count: 4,242

Corresponding author: Nathan Dawkins, Diabetes Research Centre, University of Leicester, Leicester General Hospital, Leicester, LE5 4PW, UK. Nd177@le.ac.uk. Tel: +44 116 258 4322

Number of data elements: 5

Abstract

Background: Physical activity and sleep are important for health; whether device-measured physical activity and sleep differ by ethnicity is unclear. This study aimed to compare physical activity and sleep/rest in White, South Asian (SA) and Black adults by age.

Methods: Physical activity and sleep/rest quality were assessed using accelerometer data from UK Biobank. Linear regressions, stratified by sex, were used to analyse differences in activity and sleep/rest. An ethnicity*age-group interaction term was used to assess whether ethnic differences were consistent across age-groups.

Results: Data from 95,914 participants, aged 45-79 years, were included. Overall activity was 7% higher in Black, and 5% lower in SA individuals compared to White individuals. Minority ethnic groups had poorer sleep/rest quality. Lower physical activity and poorer sleep quality occurred at a later age in Black and SA adults (>65 years), than White adults (>55 years).

Conclusions: While Black adults are more active, and SA adults less active, than White adults, the age-related reduction appears to be delayed in Black and SA adults. Sleep/rest quality is poorer in Black and SA adults than in White adults. Understanding ethnic differences in physical activity and rest differ may provide insight into chronic conditions with differing prevalence across ethnicities.

KEYWORDS: ACCELEROMETRY, SLEEP, REST, GGIR, AXIVITY

1.0. Introduction

Relative to White populations, South Asian (SA) and Black populations have a higher risk of type 2 diabetes and cardiovascular disease [1-3]. Higher amounts of physical activity, such as walking, is beneficial for treating type 2 diabetes and improving overall health [4,5]. Furthermore, as little as 10 minutes of brisk walking a day is associated with a lower risk of mortality [6], with guidelines emphasising the importance of physical activity for overall health and in the treatment and prevention of cardiometabolic disease [7,8].

Self-reported levels of moderate-to-vigorous physical activity (MVPA) are lower in some minority ethnic groups, particularly SAs [9,10]. When accelerometers are used to assess physical activity, differences between ethnic groups are less than those observed with self-reported physical activity [11-14]. Where ethnic differences are observed, they appear to be greater in women than men [13,14]. In addition to physical activity, accelerometer-assessed sleep disruption and/or irregular sleep timing is associated with poorer health outcomes [15,16] including an increased risk of cardiovascular events [17], and developing severe COVID-19 [18].

Evidence to date using accelerometer measured physical activity has been limited by small cohorts, focusing predominately on MVPA, which accounts for only a small proportion of the day [19]. Limited evidence suggests physical activity and sleep/rest behaviours may differ by ethnicity, with shorter sleep duration and higher sleep variability in those who are of an African American ethnicity [15,16]. However, rest and activity across the 24 h day have not been compared across ethnic groups.

The largest dataset with device-measured physical activity is UK Biobank which assessed over 100,000 participants using a wrist worn accelerometer [20]. Initial analysis by Doherty and colleagues described physical activity differences by sex and age. Physical activity was approximately 7.5% lower for each decade older in age [20], slightly lower than in smaller US studies showing approximately 10% decrease per decade in overall activity [21,22]. However, how device-measured physical activity and rest varies by age in people of different ethnicities in this dataset has not been examined. Therefore, examination of the profile of physical activity and sleep/rest, may facilitate greater insight into how physical activity differs between ethnicities [23].

Therefore, the primary aim of this study is to compare the rest and activity profile in women and men of White, SA and Black ethnicities. The secondary aim is to assess how the profile varies by age and whether this is consistent across ethnicities in women and men.

2.0. Material and methods

2.1. Data source and study populations

This study used data from UK Biobank, a prospective cohort study of >500,000 participants aged 40-69 years at the baseline assessment between 2006 and 2010 [24]. Participants' information was anonymised, and personal phenotypic and genotypic information collected at baseline. The use of device measured physical activity using accelerometers was an addition to the initial study and a sub-sample of 106,053 were recruited. UK Biobank study gained NHS National Research Ethics Service approval in June 2011 (Ref11/NW/0382). Details of recruitment and measurements used to obtain data for this resource can be found on the UK Biobank website: https://www.ukbiobank.ac.uk.

2.1.1. Extracted Variables

Variables used included: ethnicity, sex, month and year of birth, smoking status, self-reported medications prescribed, Townsend score (area-level measure of deprivation[25]), anthropometric variables (height, mass, body-mass index (BMI) and waist circumference), and date of the start of the accelerometer recording.

Ethnicity was categorised into White, SA and Black, as follows: White (British, Irish, White or any other White background); SA (Asian or Asian British, Indian, Pakistani or Bangladeshi); Black (Black or Black British, Caribbean, African or any other Black background). Those whose self-reported ethnicity did not fit the definition of the above three categories were excluded due to low numbers (Figure 1), this included adults who reported their ethnicity to be any of the following: Chinese, other Asian background, mixed ethnicity, other ethnic group, not known or preferred not to answer. Age at the point of accelerometer assessment was calculated from the difference between month and year of birth and the date at the start of the accelerometer device recording. Participants were categorised into age groups: 45-54 years, 55-64 years, 65-74 years, and 75-79 years; those aged under 45 years were excluded due to low numbers, in line with previous research into age group differences within UK Biobank [20].

2.2. Accelerometer and Data Collection

The Axivity AX3 accelerometer was used to assess physical activity. This is the commercial version of the Open Movement AX3 open source sensor (https://github.com/digitalinteraction/openmovement) designed by Open Lab, Newcastle University. Devices were set up to record at 100 Hz with a dynamic range of ±8 *g*. Participants were requested to wear the device continually on their dominant wrist for seven days while carrying on with their daily lives as normal.

2.3. Data Processing

The accelerometer time series data (5-second epoch) for each participant were extracted from the UK Biobank showcase. The files were converted to R-format for entry into R-package GGIR version 1.10-7 (http://cran.r-project.org) [26]. Once transformed, all accelerometer files were processed and analysed using the GGIR package to generate activity outcomes. The default GGIR settings were used to process the data. The default non-wear setting imputes invalid data by the average at similar time-points on different days of the week; therefore, the outcome variables were based on the complete 24 h cycle (1440 minutes) accounting for diurnal variation, in all participants. Participants were excluded if their accelerometer files showed fewer than one day of valid wear (defined as >16 h per day), or wear-data were not present for each 15 minute period of the 24 h cycle. Detection of non-wear has been described in detail previously [27].

As it is not possible to generate the quality control variables from the accelerometer time series 5 second epoch files, the calibration variables generated from the raw accelerometer data were also extracted: participants were excluded if they failed calibration (including those not calibrated on their own data, using a post-calibration error of greater than 0.01 *g* (10 m*g*)).

Participants were included in this study if they had one valid day of data which has been shown to be a valid measure of group level assessment previously[28]. This is based on the assumption that the one day is random, e.g., for some people that will be a weekday and for others that will be a weekend day. The following outcomes were generated and averaged across all valid days ('AD' variables in GGIR): average acceleration over 24 h (overall physical activity); intensity gradient (intensity distribution) over 24 h; acceleration (intensity) above which a person's most active X minutes or period of time (MX) are accumulated (milligravitational units (m*g*)): $M\frac{1}{3}_{DAY}$ (8 hours); M120; M60; M30, M15; M10; M5; M2; time spent in moderate-to-vigorous physical activity (MVPA) in one minute bouts; average acceleration over most active continuous sixteen hours (M16h, proxy for waking activity); average acceleration over least active continuous eight hours (L8h, proxy for sleep disruption); the variability in timing of L8h (proxy for variability in sleep timing).

Overall physical activity reflects movement during the waking day (positively associated with health) and disrupted sleep/rest (detrimentally associated with health). Thus, we used two standardised window lengths (M16h and L8h), based on national sleep recommendations (7-9 hours)[29], as proxies for waking activity and sleep/rest disruption[18]. Ongoing work in our laboratory provides preliminary evidence validating this and the proxy measures for sleep timing. Average acceleration during the least active continuous 5 hours, as in our sensitivity analysis, has been used to assess sleep disruption previously[30].

Our previous research showed that acceleration over the most active continuous 16 hours (M16h / waking activity) is associated with lower odds of severe COVID-19, while acceleration over the least active continuous 8 hours (L8h / sleep disruption) is associated with higher odds of severe COVID-19[18]. Variability in the timing of the least active continuous 8 hours is also associated with adverse COVID-19 outcomes[18]. It is also highly correlated with variability in mid-sleep time and shows similar associations with health markers in our studies in adults with type 2 diabetes (ongoing work in our laboratory). The metrics and their working abbreviations are detailed in Table 1.

2.4. Statistical Analysis

Descriptive analysis was carried out to establish the proportion of each ethnic group achieving 10 minutes of brisk walking. This was calculated as the proportion of each group with an M10 value greater than 250 m*g*.

2.4.1. Physical activity profile

Due to established differences in physical activity by sex in this cohort [20], all analyses were stratified by sex to explore differences by ethnicity and age in women and men separately. Linear regression models were used to compare overall physical activity, intensity distribution, waking activity, sleep disruption, variability in sleep timing and the balance of activity and rest between White, SA and Black ethnic groups. An interaction between ethnicity and age-group was used to assess whether differences between ethnicities were consistent across age. As the primary purpose of the analysis was to describe rather than explain differences between ethnic groups, the main model was minimally adjusted for height and weight, because of their potential to affect acceleration at a given physical activity intensity [31]. Self-reported sleep duration was also included as a covariate in models which contained the dependent variables sleep disruption and variability in sleep timing. However, in order to assess the impact of common confounding variables, a further model was also undertaking adjusting for deprivation, smoking status, medication status and cancer which are consistent with factors previously shown to have the strongest confounding effect within UK Biobank for lifestyle research[32]. L5h has been used previously as a measure of sleep assessment using accelerometer [30]. Analyses including sleep disruption or the variability in sleep timing were repeated using the L5h rather than L8h as a sensitivity analysis in order to allow for differences in the duration of sleep. Results were deemed significant at $p<0.05$. Analyses were run using Stata 16 (StataCorp LP,Texas, USA).

2.4.2. Illustration of physical activity profiles

To visualise differences in overall physical activity and intensity distribution between ethnicities, marginal means for the MX values and standardised MX values were plotted on radar plots, as previously described [23,33]. These plots illustrate the intensity profile and enable interpretation in relation to typical activities, e.g., brisk walking. Dotted/dashed circles show approximate values for slow walking (100 m*g*), brisk walking (250 m*g*) and vigorous physical activity (400 m*g*) taken from laboratory calibration studies [34]. The MX metrics were standardised within each metric relative to the mean and standard deviation (SD) of the reference group (White ethnic group [women and men combined]). The standardised values illustrate differences relative to the reference group in terms of SDs.

3.0. Results

Descriptive information for participants is presented in Table 2. Accelerometer data were available for 103,697 of the 106,053 who consented to the accelerometer sub-study [20]. Data from 95,914 participants with valid accelerometer data and complete covariate data were included (Figure 1). The demographic characteristics remained largely consistent between participants with complete data and missing data, although there is evidence that those with complete data were older, and less deprived (supplementary Table S1). Of those included in the study, mean wear time was similar across ethnic groups: 6.6 days for White adults and 6.5 days for SA and Black adults. Overall, 30.1% of participants had 7 days of wear (White: 30.1%, SA: 30.6%, Black 33.5%).

Approximately two-thirds of Black women and Black men achieved 10 minutes of brisk walking (64% and 70%, respectively) i.e., their M10 value was greater than 250 m*g*. However, this was only achieved by around half of White women (51%), White men (54%), SA women (48%) and SA men (54%).

3.1. Physical activity profile

Analysis of differences in physical activity profile by ethnicity are presented in Table 3. The pattern of differences between ethnic groups in women and men was maintained when results were further adjusted for deprivation, smoking status, medication status and cancer (see supplementary Table S2)

3.1.1. Women

Overall activity for White women was 6.4% lower than Black women but 4.6% higher than SA women ($p<0.005$) (Table 3). The intensity distribution, waking activity and time spent in MVPA followed a similar pattern to overall physical activity, although the difference between ethnicities differed for each metric. Time spent in MVPA was ~10 min/day (19.4%)

lower for SA women compared to White women and Black women undertook 5.9% more than White women ($p<0.05$) (Table 3). Sleep disruption and the variability in sleep timing were significantly lower for White women compared with SA and Black women ($p\leq 0.001$).

The MX metrics are plotted in Figures 2a and 2b. On average women achieved 2 minutes of vigorous activity and 60 minutes of slow walking regardless of their ethnicity (Figure 2a). Black women achieved 15 minutes of brisk walking whereas White and SA only achieved 10 minutes. The proportionately greater differences at higher intensities (M2 and M5) illustrate the better (higher) intensity distribution in Black women, and poorer (lower) intensity distribution in SA women, relative to White women. The standardised plot (Figure 2b) shows that Black women had the highest intensity of activity across the whole day. SA and White women had very similar values for $M⅓_{DAY}$ however, the SA women had lower intensity of activity for the remainder of the day, further illustrating their poorer intensity distribution relative to White women.

3.1.2. *Men*

Overall activity was 4.6% lower for White men than Black men but 7.5% higher than SA men ($p<0.005$) a pattern consistent with that found in women (Table 3). As with women, sleep disruption and variability in sleep timing were also the lowest in White men ($p\leq 0.001$). The intensity distribution for Black men was 1.2% higher than White men ($p=0.002$), however there was no significant difference between white and SA men (Table 3). As with women, MVPA was ~10min/day (21.9%) higher for White men compared to SA men ($p<0.001$), however there was no significant difference between White and Black men (Table 3). Waking activity followed a similar pattern to time spent in MVPA.

For the MX metrics, men on average achieved 2 minutes of vigorous activity and 60 minutes of slow walking regardless of their ethnicity. Black men achieved 15 minutes of brisk walking with White and SA men only achieving 10 minutes (Figure 2c). Consistent with the women, the proportionately greater differences at higher intensities (M2 and M5) illustrate the differences better (higher) intensity distribution in Black men, relative to White men (Figure 2d). In contrast, SA men had a more similar intensity profile to the White men but at lower intensity magnitudes, resulting in a similar intensity distribution, despite lower overall physical activity.

The sensitivity analysis using the L5h metric in-place of L8h showed a similar pattern of results.

3.1.3. Variation in activity profile by age and ethnicity

Overall, those who were older had lower physical activity, less sleep disruption and lower variability in sleep timing (supplementary Table S3). However, age x ethnicity interactions were shown for overall physical activity in both women (p = 0.002) and men (p = 0.048) (Table 3), as well as waking activity in women (p = 0.001) and intensity distribution in men (p = 0.002). Stratified analysis showed that the drop in physical activity levels with age occurred at 65+ years in SA and Black adults, while it occurred at 55+ years in White adults (Figure 3 and Figures S1). As a result, ethnic differences in physical activity metrics were less pronounced in older age groups.

Interactions were also seen for sleep disruption in men (p = 0.005) (Figure S2), such that Black men had a greater drop in sleep disturbance, but at a later age (65+ years), than White men (drop occurred at 55+ years).

4.0. Discussion

This study compares the physical activity profile between people from different ethnic groups within UK Biobank. While Black adults were more active and SA adults less active than

White adults, our data suggest that the age-related reduction in physical activity may be delayed in adults of both ethnic minorities. Furthermore, sleep was more disrupted and timing more variable in both ethnic minority groups compare to White adults irrespective of age.

Approximately two-thirds of Black women and Black men achieved 10 minutes of brisk walking, which is associated with a reduced risk of mortality [6]. Comparatively only around half of White and SA adults achieved 10 minutes of brisk walking. MVPA was 21% lower in SA adults than White adults; this is fairly consistent with the 32% difference previously reported [13]. When assessing 24 h physical activity the difference between SA and White adults was smaller: 6% for overall physical activity and 1% for intensity distribution. Assessing differences between groups using only MVPA , may inflate the magnitude of the differences, as previously reported [33]. This is illustrated in Figure 2, whereby White adults had a higher proportion of activity in the mid-intensity range (M30-M120), typically categorised as MVPA. Conversely, for short higher intensity activity (M2-M15) and long duration lower intensity activity ($M⅓_{DAY}$) SA and White adults were similar. This explains the greater differences shown for MVPA compared to 24 h physical activity.

Physical activity was lower in adults who were older, as shown previously [20,21], but notably this was not consistent across ethnicities. Overall physical activity for White adults was lower in each age group above 55 years. However, the same pattern was not seen until 65 years in both ethnic minority groups. Further, as SA adults were less active overall, the age-related decline was smaller for the oldest age group. The same pattern was noted for waking activity and intensity distribution (men only).

The social-cultural construct within different ethnic groups may contribute to these differences in physical activity pattern. Physical activity in white communities tends to focus on individualised exercises, whereas SA communities are more focussed on family based physical activity [35]. In the SA community there is greater group socialisation and social support, which is a facilitator for starting and maintaining physical activity [36]. These differences in community construct could provide some explanation as to why physical activity appears to be maintained in older SA adults but declines earlier with age in white adults. Furthermore, ethnicity is associated with deprivation and, in the UK, adults of ethnic minorities tend to be more deprived than White adults [37]. It is widely acknowledged that deprivation can have a negative impact on physical activity [38,39] and has been shown to be a driver in health in-equalities [40]. Whilst we adjusted for area level deprivation in our analyses, no data was available for individual levels of deprivation. Whilst research exists which presents possible explanations for physical activity differences between SA and White communities, there is limited available for black communities.

Whilst adults of Black ethnicity were the most active, they also had the most disrupted sleep. White adults had the least sleep disturbance, as well as the lowest variance in sleep timing compared to both ethnic minority groups. Variable sleep pattern and disrupted sleep have been shown to be detrimental for health [15,16] and may contribute to the higher prevalence of conditions such as type 2 diabetes in ethnic minorities. Higher levels of physical activity were observed for Black adults suggesting that other risk factors may be contributing to the elevated risk of diabetes and cardiovascular disease in Black adults. Whilst this falls outside the scope of this research it is something which should be explored further in future research.

UK Biobank is the largest sample with accelerometer-assessed physical activity to date [20]. Whilst the findings of this study are limited by the sample not being fully representative of the UK population, with a lower prevalence of ethnic minority group than census estimates[41], the outcomes from this dataset have been shown to be largely generalisable [42]. Nevertheless, it is possible that the low prevalence of ethnic minorities within this sample compared to the general population acted to bias observed differences in physical activity outcomes, including the higher levels of physical activity observed in Black participants. Whilst the proportion of participants from minority ethnic groups is small, the absolute numbers are larger than in previous research using device-measured physical activity[13] and with over 700 participants in each groups, is one of the most comprehensive investigations into ethnic differences in accelerometer assessed physical activity and sleep profiles to date. This study is also limited by the accelerometer data collection occurring at a later date to the baseline data. Whilst this creates a gap between the two points of data collection, variables have been shown to be stable over this period [43].

Future research should explore whether these differences in physical activity and rest/sleep are confirmed in cohorts that are generalizable to the general population and whether they contribute to ethnic differences in health. This could include the mechanisms behind these differences or establishing whether they may result in a reduced risk of developing cardiometabolic diseases. Research may also explore factors which may explain these differences in physical activity exist, for example the effect of light pollution, access to green spaces or shift worker status.

5.0. Conclusion

In conclusion, Black men and women had higher overall activity and more favourable intensity distribution of activity than White adults, who had higher values compared to SA ethnicities. In both sexes, white adults had less sleep disruption and less variance in sleep timing compared to both minority ethnic groups. Those who were older had lower physical activity levels but also less sleep disturbance. The age-related decline in physical activity appears to differ by ethnicity, with lower physical activity and greater sleep disruption evident in White adults from the age of 55 years, but not until the age of 65 years in Black and SA adults. Understanding how physical activity differs in terms of age and ethnicity may contribute to ethnic differences in health thus is important to inform physical activity interventions and targeted health messaging.

Data Source

This research has been conducted using the UK Biobank Resource under Application Number 36371

Acknowledgements

Author Contributions: NPD, AVR and TY planned the study. NPD completed the main analysis of the study, with contributions from AVR, TY and CR. NPD prepared the first draft of the manuscript. All authors read, provided feedback and approved the final manuscript.

University of Leicester authors are supported by the NIHR Leicester Biomedical Research Centre, and the NIHR Applied Research Collaboration (ARC) East Midlands. The views expressed are those of the authors and not necessarily those of the NHS, NIHR, or Department of Health.

Conflict of interest

The authors report no conflict of interest.

Funding

No funding was received to conduct this research.

6.0. References

1. Tillin T, Hughes AD, Godsland IF, et al. Insulin resistance and truncal obesity as important determinants of the greater incidence of diabetes in Indian Asians and African Caribbeans compared with Europeans: the Southall And Brent REvisited (SABRE) cohort. *Diabetes care*. 2013;36(2):383-393.
2. Gopal DP, Usher-Smith JA. Cardiovascular risk models for South Asian populations: a systematic review. *International journal of public health*. 2016;61(5):525-534.
3. Ferguson L, Ntuk U, Celis-Morales C, et al. Men across a range of ethnicities have a higher prevalence of diabetes: findings from a cross-sectional study of 500 000 UK Biobank participants. *Diabetic Medicine*. 2018;35(2):270-276.
4. Di Loreto C, Fanelli C, Lucidi P, et al. Make your diabetic patients walk: long-term impact of different amounts of physical activity on type 2 diabetes. *Diabetes care*. 2005;28(6):1295-1302.
5. Hamasaki H. Daily physical activity and type 2 diabetes: A review. *World journal of diabetes*. 2016;7(12):243.
6. Chudasama YV, Khunti KK, Zaccardi F, et al. Physical activity, multimorbidity, and life expectancy: a UK Biobank longitudinal study. *BMC medicine*. 2019;17(1):108. doi:https://doi.org/10.1186/s12916-019-1339-0
7. NICE. Type 2 diabetes in adults:

management. https://www.nice.org.uk/guidance/ng28/resources/type-2-diabetes-in-adults-management-1837338615493
8. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British journal of sports medicine*. 2020;54(24):1451-1462.
9. Williams ED, Stamatakis E, Chandola T, Hamer M. Assessment of physical activity levels in South Asians in the UK: findings from the Health Survey for England. *Journal of Epidemiology & Community Health*. 2011;65(6):517-521.
10. Yates T, Davies M, Gray L, et al. Levels of physical activity and relationship with markers of diabetes and cardiovascular disease risk in 5474 white European and South Asian adults screened for type 2 diabetes. *Preventive medicine*. 2010;51(3-4):290-294.
11. Iliodromiti S, Ghouri N, Celis-Morales CA, Sattar N, Lumsden MA, Gill JM. Should physical activity recommendations for South Asian adults be ethnicity-specific? Evidence from a cross-sectional study of South Asian and White European men and women. *PloS one*. 2016;11(8):e0160024.
12. Yates T, Henson J, Edwardson C, Bodicoat DH, Davies MJ, Khunti K. Differences in levels of physical activity between White and South Asian populations within a healthcare setting: impact of measurement type in a cross-sectional study. *BMJ open*. 2015;5(7)
13. Biddle GJ, Edwardson CL, Rowlands AV, et al. Differences in objectively measured physical activity and sedentary behaviour between white Europeans and south Asians recruited from primary care: cross-sectional analysis of the PROPELS trial. *BMC public health*. 2019;19(1):95. doi:https://doi.org/10.1186/s12889-018-6341-5
14. Yates T, Edwardson CL, Celis-Morales C, et al. Metabolic effects of breaking prolonged sitting with standing or light walking in older South Asians and White Europeans: A randomized acute study. *The Journals of Gerontology: Series A*. 2020;75(1):139-146. doi:https://doi.org/10.1093/gerona/gly252
15. Huang T, Redline S. Cross-sectional and prospective associations of actigraphy-assessed sleep regularity with metabolic abnormalities: the Multi-Ethnic Study of Atherosclerosis. *Diabetes Care*. 2019;42(8):1422-1429.

16. Brouwer A, Van Raalte DH, Rutters F, et al. Sleep and HbA1c in patients with type 2 diabetes: Which sleep characteristics matter most? *Diabetes Care*. 2020;43(1):235-243.
17. Huang T, Mariani S, Redline S. Sleep irregularity and risk of cardiovascular events: the multi-ethnic study of atherosclerosis. *Journal of the American College of Cardiology*. 2020;75(9):991-999.
18. Rowlands AV, Kloecker DE, Chudasama Y, et al. Association of Timing and Balance of Physical Activity and Rest/Sleep With Risk of COVID-19: A UK Biobank Study. Elsevier; 2020:
19. Rowlands AV, Edwardson CL, Davies MJ, Khunti K, Harrington DM, Yates T. Beyond Cut Points: Accelerometer Metrics that Capture the Physical Activity Profile. *Med Sci Sports Exerc*. Jun 2018;50(6):1323-1332. doi:10.1249/MSS.0000000000001561
20. Doherty A, Jackson D, Hammerla N, et al. Large Scale Population Assessment of Physical Activity Using Wrist Worn Accelerometers: The UK Biobank Study. *Plos One*. Feb 1 2017;12(2):e0169649. doi:ARTN e0169649

10.1371/journal.pone.0169649
21. Schrack JA, Zipunnikov V, Goldsmith J, et al. Assessing the "physical cliff": detailed quantification of age-related differences in daily patterns of physical activity. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences*. 2014;69(8):973-979.
22. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Medicine & Science in Sports & Exercise*. 2008;40(1):181-188.
23. Rowlands AV, Dawkins NP, Maylor B, et al. Enhancing the value of accelerometer-assessed physical activity: meaningful visual comparisons of data-driven translational accelerometer metrics. *Sports Medicine-Open*. 2019;5(1):1-11.
24. Sudlow C, Gallacher J, Allen N, et al. UK biobank: an open access resource for identifying the causes of a wide range of complex diseases of middle and old age. *PLoS Med*. Mar 2015;12(3):e1001779. doi:10.1371/journal.pmed.1001779
25. Townsend P. Deprivation. *Journal of social policy*. 1987;16(2):125-146.
26. 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):188-196.
27. van Hees VT, Gorzelniak L, Dean Leon EC, et al. Separating movement and gravity components in an acceleration signal and implications for the assessment of human daily physical activity. *PLoS One*. 2013;8(4):e61691. doi:10.1371/journal.pone.0061691
28. Wolff-Hughes DL, McClain JJ, Dodd KW, Berrigan D, Troiano RP. Number of accelerometer monitoring days needed for stable group-level estimates of activity. *Physiological measurement*. 2016;37(9):1447.
29. Hirshkowitz M, Whiton K, Albert SM, et al. National Sleep Foundation's sleep time duration recommendations: methodology and results summary. *Sleep health*. 2015;1(1):40-43. doi:https://doi.org/10.1016/j.sleh.2014.12.010
30. Migueles JH, Martinez-Nicolas A, Cadenas-Sanchez C, et al. Activity-rest circadian pattern and academic achievement, executive function and intelligence in children with obesity. *Scandinavian Journal of Medicine & Science in Sports*. 2021;31(3):653-64. doi:https://doi.org/10.1111/sms.13862
31. Stone MR, Esliger DW, Tremblay MS. Comparative validity assessment of five activity monitors: does being a child matter? *Pediatric Exercise Science*. 2007;19(3):291-309.
32. Zaccardi F, Franks PW, Dudbridge F, Davies MJ, Khunti K, Yates T. Mortality risk comparing walking pace to handgrip strength and a healthy lifestyle: a UK Biobank study. *European journal of preventive cardiology*. 2021;28(7):704-712.
33. Dawkins NP, Yates T, Edwardson CL, et al. Comparing 24 h physical activity profiles: Office workers, women with a history of gestational diabetes and people with chronic disease condition(s). *Journal of Sports Sciences*. 2020:1-8. doi:10.1080/02640414.2020.1812202

34. Hildebrand M, Van Hees VT, Hansen BH, Ekelund U. Age group comparability of raw accelerometer output from wrist-and hip-worn monitors. *Medicine and science in sports and exercise*. 2014;46(9):1816-1824.
35. Gupta SS, Aroni R, Teede H. Experiences and perceptions of physical activity among South Asian and Anglo-Australians with type 2 diabetes or cardiovascular disease: implications for clinical practice. *Qualitative health research*. 2017;27(3):391-405.
36. Horne M, Skelton D, Speed S, Todd C. Attitudes and beliefs to the uptake and maintenance of physical activity among community-dwelling South Asians aged 60–70 years: A qualitative study. *Public Health*. 2012;126(5):417-423.
37. GOV. People living in deprived neighbourhoods: Percentage of people living in the most deprived 10% of neighbourhoods, by ethnicity. Accessed 11/02/2021, https://www.ethnicity-facts-figures.service.gov.uk/uk-population-by-ethnicity/demographics/people-living-in-deprived-neighbourhoods/latest
38. Eime RM, Harvey J, Charity MJ, Casey M, Westerbeek H, Payne WR. The relationship of sport participation to provision of sports facilities and socioeconomic status: a geographical analysis. *Australian and New Zealand journal of public health*. 2017;41(3):248-255.
39. Powell LM, Slater S, Chaloupka FJ. The relationship between community physical activity settings and race, ethnicity and socioeconomic status. *Evidence-Based Preventive Medicine*. 2004;1(2):135-44.
40. Razieh C, Zaccardi F, Islam N, et al. Ethnic minorities and COVID-19: Examining whether excess risk is mediated through deprivation. *European Journal of Public Health*. 2021;
41. Fry A, Littlejohns TJ, Sudlow C, et al. Comparison of sociodemographic and health-related characteristics of UK Biobank participants with those of the general population. *American journal of epidemiology*. 2017;186(9):1026-1034.
42. Batty GD, Gale CR, Kivimäki M, Deary IJ, Bell S. Comparison of risk factor associations in UK Biobank against representative, general population based studies with conventional response rates: prospective cohort study and individual participant meta-analysis. *bmj*. 2020;368
43. Strain T, Wijndaele K, Dempsey PC, et al. Wearable-device-measured physical activity and future health risk. *Nature medicine*. 2020;26(9):1385-1391.

Tables and figures list

Table 1. Description of the physical activity metrics used in the paper.

Table 2. Descriptive data, by ethnicity.

Table 3. Physical activity and sleep/rest metrics by ethnic group, including the interaction between ethnicity and age-group (45-54 years; 55-64 years; 65+ years).

Figure 1. Participant flow diagram.

Figure 2. MX values for all three ethnicities. The red dashed lines represent indicative values for: slow walking (–), brisk walking (. . .) and vigorous activity (._._) [34]. W = White ethnicity, SA = South Asian, B = Black ethnicity. (a) Women mean MX values (m*g*); (b) Women standardised MX values; (c) Men mean MX values; (d) Men standardised MX values.

Figure 3. Overall physical activity values for women and men by ethnicity and age group. Values are mean + standard error. W = White ethnicity; SA = South Asian ethnicity; B = Black ethnicity. * = significant age and ethnicity interaction ($p<0.05$).

List of supplementary materials

Table S1: Participant characteristics by missing data status.

Table S2. Physical activity and sleep/rest metrics by ethnic group, including the interaction between ethnicity and age-group (45-54 years; 55-64 years; 65+ years).

Table S3. Marginal means for physical activity and sleep/rest metrics by age-group in the fully adjusted model.

Tables

Table 1. Description of the physical activity metrics used in the paper.

Metric	Unit	Abbreviation	Interpretation
Physical Activity			
Average acceleration	m*g*	Overall physical activity	The average of all accelerations across the 24 h day, a proxy for total physical activity
Moderate-to-vigorous physical activity	minutes	MVPA	Time spent in physical activity above 3 METS. Derived using an acceleration threshold of 100 m*g* [34].
Intensity gradient	N/A	Intensity distribution	Reflects the distribution of acceleration intensity across the 24 h day. It is always negative; a lower (more negative) value indicates time is mainly spent inactive and at lower intensities, while a higher (less negative) value indicates people are also accumulating time at higher intensities [19,23].
MX	m*g*	M(time period) e.g. 10 minutes = M10	The acceleration above which a person's most active X minutes are accumulated, where X = time. The activity can be accumulated at any point across the day, i.e., it does not need to be continuous or in bouts. For example, M10 is the intensity that a person exceeded for a total of 10 minutes across the day. If the M10 exceeds 250 m*g* (acceleration threshold for brisk walking[6]), this indicates 10 minutes of activity at an intensity equivalent to at least brisk walking.
Activity and sleep/rest			
Average acceleration over most active continuous 16 h	m*g*	Waking activity	The average of all accelerations during the most active continuous 16 h of the day as a proxy for waking hours. Greater values present a higher level of physical activity within this window.
Average acceleration over least active continuous 8 h*	m*g*	Sleep disruption	The average of all accelerations during the least active continuous 8 h of the day sleep/rest as a proxy for the sleep window (main rest period). Lower values represent a more restful window of recovery.
Variability in timing of activity and sleep/rest			

Variability (SD) in the start time of the least active continuous 8 h*	minutes	Variability in sleep timing	Calculated as the SD of the start time of the least active continuous 8 h for all valid nights Proxy for variability in time of sleep onset.

MVPA = moderate-to-vigorous physical activity

Acceleration cut-point for classification of MVPA = 100 m*g*[34]

* Measures were repeated using the L5h metric as a sensitivity analysis

Table 2. Descriptive data by ethnicity.

Variable		White (N=94,359)		South Asian (N=738)		Black (N=817)	
		Women (N = 53,062)	Men (N = 41,297)	Women (N = 328)	Men (N = 410)	Women (N = 502)	Men (N = 315)
Continuous variables							
Age		62.1 (7.7)	63.2 (7.8)	57.6 (7.7)	59.4 (8.7)	55.5 (6.9)	56.7 (7.2)
Height (cm)	All ages	163.5 (6.1)	176.5 (6.6)	158.2 (6.0)	171.3 (6.0)	163.0 (6.3)	175.0 (7.0)
	45-54 years	165.0 (6.2)	178.2 (6.6)	159.1 (5.5)	172.2 (5.8)	164.1 (6.1)	176.2 (7.1)
	55-64 years	163.8 (6.1)	177.0 (6.6)	157.8 (6.6)	171.9 (6.0)	162.4 (6.1)	174.7 (6.6)
	65+ years	162.5 (6.0)	175.6 (6.4)	156.7 (5.7)	169.6 (6.0)	160.2 (6.4)	171.8 (6.7)
Weight (kg)	All ages	70.1 (13.3)	85.1 (13.6)	65.2 (11.0)	78.2 (12.0)	77.9 (15.6)	87.4 (14.5)
	45-54 years	70.2 (14.1)	85.8 (14.1)	65.1 (11.4)	79.7 (13.0)	77.8 (16.3)	88.2 (14.8)
	55-64 years	70.5 (13.6)	85.9 (14.2)	64.9 (10.6)	78.3 (11.1)	78.6 (15.2)	87.9 (14.7)
	65+ years	69.8 (12.5)	84.3 (12.9)	66.0 (11.1)	76.5 (11.7)	76.8 (13.0)	83.8 (12.4)
BMI (kg/m^2)	All ages	26.2 (4.8)	27.3 (4.0)	26.1 (4.5)	26.6 (3.6)	29.3 (5.6)	28.5 (4.0)
	45-54 years	25.8 (5.1)	27.0 (4.1)	25.7 (4.4)	26.8 (3.9)	28.9 (5.7)	28.3 (3.8)
	55-64 years	26.3 (4.9)	27.4 (4.2)	26.1 (4.3)	26.5 (3.3)	29.8 (5.4)	28.8 (4.4)
	65+ years	26.4 (4.6)	27.3 (3.9)	26.9 (5.0)	26.5 (3.4)	30.0 (5.1)	28.4 (3.7)
Deprivation	All ages	-1.76 (2.8)	-1.84 (2.8)	-0.36 (2.9)	-0.50 (2.9)	1.87 (3.3)	1.90 (3.7)
	45-54 years	-1.38 (2.9)	-1.35 (3.0)	-0.32 (2.9)	-0.40 (2.8)	1.94 (3.3)	2.03 (3.5)
	55-64 years	-1.76 (2.8)	-1.78 (2.8)	-0.32 (2.9)	-0.51 (3.1)	1.74 (3.3)	2.11 (3.9)
	65+ years	-1.97 (2.7)	-2.09 (2.6)	-0.54 (2.9)	-0.62 (2.9)	1.91 (3.3)	0.85 (4.1)
Self-reported	All ages	7.2 (1.0)	7.2 (1.0)	7.0 (1.1)	7.0 (1.2)	6.7 (1.3)	6.5 (1.2)

sleep duration (hours)	45-54 years	7.3 (0.9)	7.0 (0.9)	7.1 (1.0)	6.9 (1.0)	6.7 (1.4)	6.5 (1.0)
	55-64 years	7.1 (1.0)	7.0 (0.9)	6.8 (1.1)	7.0 (1.4)	6.6 (1.2)	6.3 (1.2)
	65+ years	7.2 (1.0)	7.3 (1.0)	7.1 (1.1)	7.3 (1.0)	6.7 (1.3)	7.0 (1.5)
Categorical variables							
Smoking Status (never)	All ages	31,988 [60.5]	21,354 [51.9]	300 [91.7]	267 [65.6]	381 [76.4]	190 [60.5]
	45-54 years	7,396 [64.2]	4,877 [62.6]	132 [93.6]	97 [67.4]	200 [73.8]	96 [66.2]
	55-64 years	12,020 [61.2]	7,479 [56.0]	104 [88.1]	93 [67.4]	127 [76.1]	64 [53.3]
	65+ years	12,572 [57.9]	8,998 [45.0]	64 [94.1]	77 [61.6]	54 [88.5]	30 [61.2]
Number of medications (no medications)	All ages	14,505 [27.4]	14,077 [34.2]	100 [30.6]	157 [38.6]	138 [27.7]	123 [39.2]
	45-54 years	3,857 [33.5]	3,801 [48.8]	56 [39.7]	80 [55.7]	92 [34.0]	71 [49.0]
	55-64 years	5,845 [29.8]	5,251 [39.3]	28 [23.7]	53 [38.4]	41 [24.6]	47 [39.2]
	65+ years	4,803 [22.1]	5,025 [25.1]	16 [23.5]	24 [19.2]	5 [8.2]	5 [10.2]
Cancers (no cancer)	All ages	47,868 [90.5]	38,562 [93.7]	313 [95.7]	396 [97.3]	475 [95.2]	306 [97.5]
	45-54 years	10,392 [95.0]	7,609 [97.6]	138 [97.9]	143 [99.3]	261 [96.3]	144 [99.3]
	55-64 years	18,020 [91.7]	12,760 [95.5]	112 [94.9]	137 [99.3]	158 [94.6]	117 [97.5]
	65+ years	18,916 [87.0]	18,193 [90.9]	63 [92.7]	116 [92.8]	56 [91.8]	45 [91.8]

Data as mean (standard deviation) or N [%]
Deprivation is calculated using the Townsend score, negative = less deprived, positive = more deprived.

Table 3. Physical activity and sleep/rest metrics by ethnic group, including the interaction between ethnicity and age-group (45-54 years; 55-64 years; 65+ years).

	Women				Men			
Variable	White	South Asian	Black	Ethnicity X age Interaction†	White	South Asian	Black	Ethnicity X age Interaction†
Overall physical activity (m*g*)	28.7 (28.6, 28.7)	**27.4 (26.6, 28.2)**	**30.6 (29.8, 31.3)**		27.7 (27.6, 27.8)	**25.7 (24.9, 26.4)**	**29.0 (27.9, 30.0)**	
p-value	-	**0.002**	**<0.001**	**0.002**	-	**<0.001**	**0.016**	**0.048**
Intensity distribution	-2.58 (-2.58, -2.57)	**-2.62 (-2.64, -2.60)**	**-2.55 (-2.57, -2.54)**		-2.51 (-2.51, -2.51)	-2.52 (-2.54, -2.50)	**-2.48 (-2.50, -2.46)**	
p-value	-	**<0.001**	**0.002**	0.364	-	0.385	**0.002**	**0.004**
MVPA (minutes per day)	47.5 (47.2, 47.7)	**39.1 (35.9, 42.3)**	**50.4 (47.7, 53.1)**		48.6 (48.3, 48.9)	**39.0 (36.0, 42.1)**	48.0 (44.6, 51.4)	
p-value	-	**<0.001**	**0.036**	0.177	-	**<0.001**	0.739	0.157
Waking activity (m*g*)	41.0 (40.9, 41.0)	**38.7 (37.5, 39.8)**	**42.8 (41.8, 43.9)**		39.3 (39.2, 39.5)	**36.0 (34.9, 37.0)**	40.4 (38.9, 41.8)	
p-value	-	**<0.001**	**0.001**	**0.001**	-	**<0.001**	0.179	0.085
Sleep disturbance* (m*g*)	4.12 (4.11, 4.13)	**4.76 (4.52, 5.00)**	**5.78 (5.51, 6.05)**		4.38 (4.36, 4.40)	**5.08 (4.87, 5.30)**	**6.05 (5.71, 6.39)**	
p-value	-	**<0.001**	**<0.001**	0.818	-	**<0.001**	**<0.001**	**0.005**
Variability in sleep timing* (minutes)	43.9 (43.6, 44.2)	**54.4 (48.0, 60.7)**	**69.3 (63.8, 74.9)**		48.0 (47.6, 48.4)	**57.5 (52.9, 62.1)**	**79.3 (69.3, 89.3)**	
p-value	-	**0.001**	**<0.001**	0.361	-	**<0.001**	**<0.001**	0.091

Data as a marginal mean (95% confidence interval).
MVPA = Moderate-to-vigorous physical activity, calculated in 1-minute bouts.
Covariates included: height, weight. Self-reported sleep duration was also included as a covariate in models which contained the dependent variables sleep disruption and variability in sleep timing.
P value for each ethnicity (excluding interaction term) indicates difference compared to White of the same sex.
Bold indicates significant at P<0.05.
* L5h derived version of the metric also analysed as part of a sensitivity analysis. Findings of both metrics were consistent.
† Main effect for age were evident for all metrics. Values were lower for the 55-65 years and the 65+ years for all metrics (supplementary document Table S3).

Figures

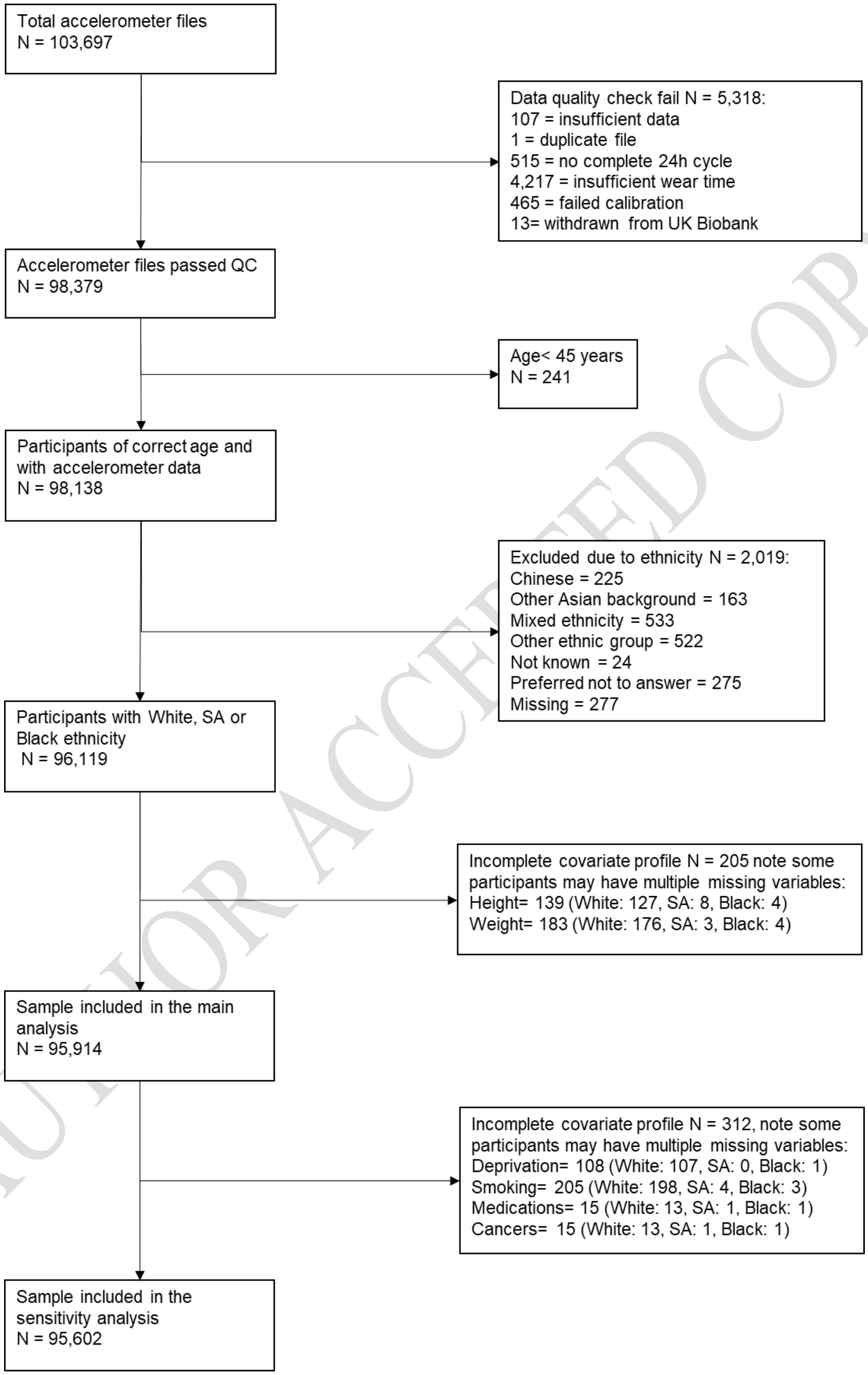

Figure 1. Participant flow diagram. SA = South Asian.

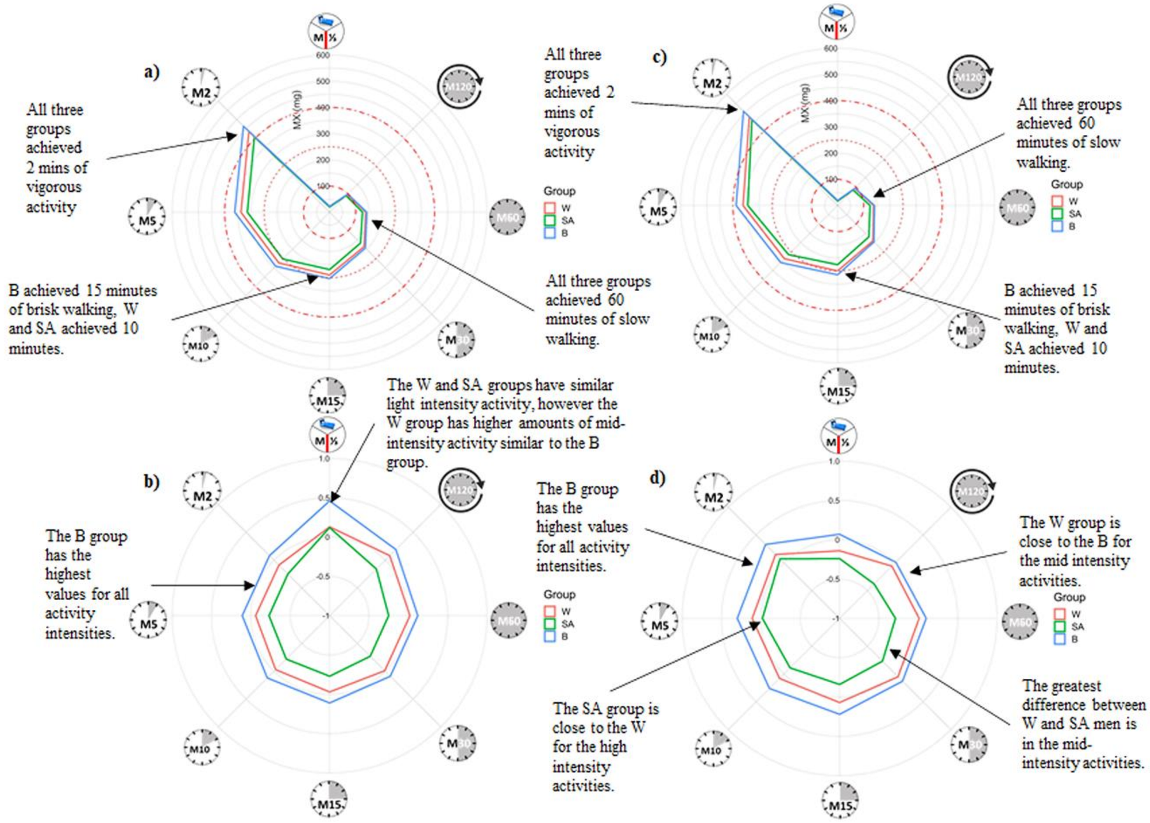

Figure 2. MX values for all three ethnicities. The red dashed lines represent indicative values for: slow walking (–), brisk walking (. . .) and vigorous activity (._._.) [34]. W = White ethnicity, SA = South Asian, B = Black ethnicity. (a) Women mean MX values (m*g*); (b) Women standardised MX values; (c) Men mean MX values; (d) Men standardised MX values.

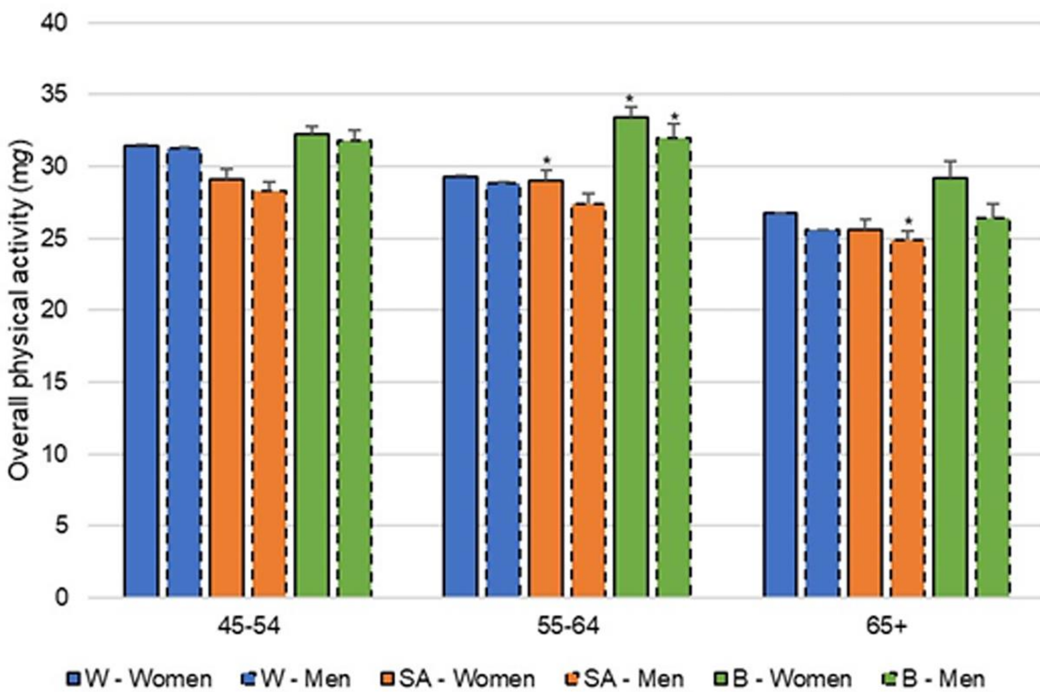

Figure 3. Overall physical activity values for women and men by ethnicity and age group. Values are mean + standard error. W = White ethnicity; SA = South Asian ethnicity; B = Black ethnicity. * = significant age and ethnicity interaction (p<0.05).