OBJECTIVELY MEASURED MODERATE AND VIGOROUS INTENSITY PHYSICAL ACTIVITY BUT NOT SEDENTARY TIME PREDICTS INSULIN RESISTANCE IN HIGH RISK INDIVIDUALS

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**Objective** - Low levels of physical activity (PA) appear to be associated with insulin resistance (IR). However, the detailed associations of these complex relationships remain elusive. We examined the prospective associations between self-reported TV-viewing time, objectively measured time spent sedentary, at light (LPA), and moderate and vigorous intensity physical activity (MVPA) with IR.

**Research design and methods** – In 192 individuals (81 men, 111 women) with a family history of type 2 diabetes we measured PA, anthropometric and metabolic variables at baseline and after 1 year of follow-up in the ProActive UK trail. Physical activity was measured objectively by accelerometry. IR was expressed as fasting insulin and the homeostasis model assessment score (HOMA).

**Results** - Baseline MVPA was a significant predictor of fasting insulin at follow-up ($\beta$=-0.004, 95% CI; -0.007; -0.0001, $P=0.022$), and the association approached significance for HOMA-IR ($\beta$=-0.003, 95% CI; -0.007; 0.000002, $P=0.052$), independent of time spent sedentary, at light intensity activity, sex, age, smoking status, waist circumference and self-reported TV viewing. Time spent sedentary and at LPA were not significantly associated with IR. Change in MVPA between baseline and follow-up was inversely related to fasting insulin ($\beta$=-0.003, 95% CI; -0.007; -0.0003, $P=0.032$) and the HOMA score ($\beta$=-0.004, 95% CI; -0.008; -0.001, $P=0.015$) at follow-up, after adjusting for baseline phenotype in addition to the same confounders as above.

**Conclusion** - These results highlight the importance of promoting moderate intensity activity such as brisk walking for improving insulin sensitivity and possibly other metabolic risk factors to prevent type 2 diabetes.
Insulin resistance, considered by some to be the underlying cause of the metabolic syndrome, is an important factor in the etiology of type 2 diabetes and also a strong independent predictor of the disease even in individuals with normal glucose levels (1).

Potentially modifiable risk factors for insulin resistance include age, overall and abdominal obesity, dietary factors, sedentary behaviour and low levels of physical activity (1). Sedentary behaviour, defined as self-reported TV-viewing or total sitting time is associated with abnormal glucose metabolism (2, 3), the metabolic syndrome (4), and predicts obesity and type 2 diabetes in women (5). More recent studies using motion sensors based on accelerometry for assessing time spent sedentary have suggested that total time, and uninterrupted sedentary time is associated with metabolic risk and 2-hour post challenge glucose (6, 7).

Other studies using individually calibrated heart rate monitoring for assessing physical activity energy expenditure (PAEE) have observed a cross-sectional association between PAEE with a clustered metabolic risk score (i.e. the standardized sum of the individual components) (8), that PAEE predicts progression toward the metabolic syndrome (9), and that change in PAEE predicts clustered metabolic risk independent of change in adiposity and cardio-respiratory fitness (10). In agreement with these observations, there is evidence to suggest that total physical activity measured by accelerometry is associated with insulin resistance and clustered metabolic risk (11, 12) and that small increases in total physical activity is associated with a reduction in metabolic risk (13).

However, none of these studies examined the independent prospective associations between different sub-components of objectively measured physical activity, i.e. time spent sedentary, at light and at moderate and vigorous intensity physical activity (MVPA) and self-reported TV-viewing with insulin resistance. This is important since existing guidelines on physical activity for public health emphasise the importance of MVPA but do not consider the potential harmful effects of sedentary living.

Therefore the aim of the present study was to examine the independent prospective associations between time spent sedentary, at light intensity and at MVPA and self-reported TV-viewing with insulin resistance in a cohort analysis of the ProActive UK trial (14). We hypothesised that objectively measured time spent at MVPA predicts insulin resistance independent of time spent at lower intensity levels and self-reported TV-viewing.

**RESEARCH DESIGN AND METHODS**

**Study population:** The present study is a cohort analysis of the ProActive UK trial which has been extensively described previously (14). Briefly, ProActive aimed to evaluate the efficacy of a theoretical, evidence- and family-based intervention programme to increase physical activity among individuals defined as high-risk through having a parental history of type 2 diabetes. 465 individuals were eligible and of these 399 were recruited for baseline measurements and randomly assigned to one of three interventions as previously described (14). Complete data on anthropometry and biochemistry were available in 365 participants at
baseline and 321 participants at 1-yr follow-up, in addition to socio-demographic information. Main trial results indicated no significant difference between the three trial arms in the 1-year change in objectively measured daytime physical activity or in the outcomes included in the present manuscript (14). Consequently, the three trial arms were pooled and a cohort analysis conducted. Physical activity measured by accelerometry was measured in a sub-sample of participants (n=192) at baseline and follow-up and constitutes the sample for the present study. The measure of socioeconomic status (SES) was based on age at finishing full-time education (above or below 16 years). Time (h per week) spent viewing TV and video and smoking status (never, former, current) were assessed with questionnaire at baseline and follow-up. All participants provided written informed consent and ethical permission for the study was granted by the Eastern England Multi-centre Research Ethics Committee.

Anthropometric and metabolic tests

After an overnight fast and a sample of venous blood was taken from each individual. Fasting plasma glucose and serum insulin levels were measured using the hexokinase method at baseline and follow-up as described previously (14). We used both fasting insulin and the homeostasis model assessment (HOMA) as indicators of insulin resistance. HOMA-IR was calculated as fasting plasma glucose (mmol/l) times fasting serum insulin (mU/l) divided by 22.5.

Weight was measured on standard calibrated scales and height was measured using a rigid stadiometer. BMI was calculated as weight (kg) divided by height (m) squared. Overweight and obesity was defined as BMI > 25 and >30 kg·m⁻², respectively. Waist circumference (cm) was measured over light indoor clothing as the mid-point between the lower costal margin and the level of the anterior superior iliac crests. Resistance (Ω) was assessed using a standard bioimpedance technique (Bodystat, Isle of Man, UK). Total body water (TBW) and fat-free mass (FFM) were calculated using the impedance index (height²/resistance), and body weight and resistance. Fat mass (FM) was calculated as body weight minus FFM. Systolic and diastolic blood pressures were measured using an automated Accutorr sphygmomanometer (Accutorr, Cambridge, UK). Exactly the same measurements and analytical procedures were applied at baseline and follow-up.

Physical activity by accelerometry: Physical activity was measured with accelerometry (MTI Actigraph, model WAM 7164, Manufacturing Technology Inc. Fort Walton Beach, FL) over four consecutive days at baseline and follow-up as previously described (11). Non-wear time was identified as continuous zero movement lasting longer than 60 min. Using this criteria, seven individuals were excluded as they did not manage to record at least 500 minutes per day of activity for at least three days during either baseline or follow-up. Outcome variables from the activity monitor included time (min·d⁻¹) spent at different activity intensity categories averaged per day over the measurement period. Intensity thresholds for moderate (1952 – 5724 counts min⁻¹) and vigorous intensity activity (> 5725 counts min⁻¹) were defined (15). Sixty percent of participants did not accumulate any time in vigorous intensity physical activity at baseline. We therefore constructed a single variable by combining accumulated time in moderate and vigorous intensity activity. Sedentary behaviour was defined as < 100
counts min\(^{-1}\) and light intensity activity as 101 – 1951 counts min\(^{-1}\). The cut-off for sedentary behaviour is an arbitrary threshold, which we and others have used previously (6, 7, 11). Data reduction, cleaning and analyses of accelerometer data were performed using a special written programme (MAHffe; www.mrc-epid.cam.ac.uk). Individuals were also categorised above or below accumulating at least 30 minutes per day of time spent at MVPA according to current recommendations for public health (16).

**Statistical analyses:** Descriptive characteristics are summarised as means and standard deviations (SD) at baseline and follow-up. Fasting insulin and HOMA were logarithmically transformed owing to their skewed distributions (geometric mean and 95% confidence intervals are presented in the results). Associations between variables were examined using Pearson correlation coefficients and partial correlation coefficients. Differences between gender and between baseline and follow-up was analysed by ANOVA.

To examine which, if any, of the objectively measured sub-components of physical activity and self-reported TV and video viewing were independently associated with insulin resistance, we fitted multiple linear regression models with either fasting insulin or HOMA as the outcome and objectively measured time spent sedentary, at light, at MVPA, and self-reported TV-viewing as exposure variables. In the first cross-sectional model we adjusted for age, sex, smoking status (current, ex, never), and waist circumference. To examine whether physical activity sub-components and video and TV-viewing independently predicted insulin resistance at follow-up we modelled insulin resistance (fasting insulin or HOMA) at follow-up as outcome variables and objectively measured time spent sedentary, at light, at MVPA, and self-reported TV-viewing measured at baseline as exposure variables. In addition to the confounders described above, we also adjusted our prospective models for follow-up time and baseline insulin resistance (i.e. fasting insulin or HOMA). Finally, we examined whether change in physical activity sub-components and TV-viewing (follow-up minus baseline values) was associated with insulin resistance at follow-up after adjusting for all confounding factors described above. In all multiple linear regression models, multicollinearity was controlled for by means of the variance inflation factor. Including intervention arm (3 categories) in our analyses did not change the direction or magnitude of associations observed and was therefore removed from our final models. All data were analysed in its continuous form but stratified above and below accumulating at least 30 minutes per day of time spent at MVPA and obesity status (normal-weight, overweight, obese) for illustrative purposes. All analyses were conducted using SPSS for Windows (Ver. 13, SPSS Inc. Chicago, Il).

**RESULTS**

Table 1 display the descriptive characteristics of participants at baseline and follow-up. The mean follow-up time was 405 ± 103 days. Men were heavier, taller and had a higher FFM than women (P<0.001). Fasting
glucose (P<0.01), insulin (P<0.001) and the HOMA-IR score (P < 0.001) were also significantly higher in men than women, whereas FM was higher in women (P<0.001). Forty-nine percent of men and 36% of women were overweight and additionally 27% of both men and women were obese.

Men spent more time sedentary (P<0.01) whereas women spent more time at light intensity activity (P<0.05). In contrast, men reported significantly lower levels of TV-viewing (P<0.001). Self-reported TV-viewing decreased significantly between baseline and follow-up (P<0.05) whereas all other variables remained unchanged. We did not observe any significant sex by time interactions. All subsequent analyses are therefore analysed with men and women combined, adjusted for sex.

Time spent sedentary was significantly and inversely associated with time spent at light intensity activity at baseline and follow-up (r=-0.52, P<0.0001; r=-0.48, P<0.0001) and time spent at light intensity activity was significantly and positively correlated with time spent at MVPA at follow-up (r=0.24, P=0.009) but not as baseline. Self-reported TV-viewing was significantly and inversely associated time spent at light intensity activity at baseline and follow-up (r=-0.16, P=0.027; r=-0.24, P=0.001) but not associated with any of the other objectively measured time estimates. Self-reported TV-viewing at baseline was significantly correlated with TV-viewing at follow-up (r=0.78, P<0.001). Similarly, all objectively measured time estimates at baseline were significantly correlated with their corresponding time estimates at follow-up (r=0.61 to 0.63, P<0.0001), indicating a high degree of stability of patterns of physical activity.

Table 2 shows the cross-sectional and prospective associations between time estimates of physical activity, self-reported TV-viewing with insulin resistance. In cross-sectional analyses, time (min d^{-1}) spent at MVPA was significantly and inversely associated with HOMA (β=-0.004, 95% CI; -0.008; -0.00001, P=0.048) and fasting insulin (β=-0.005, 95% CI; -0.008; -0.001, P=0.017), independent of time spent sedentary, at light intensity activity, sex, age, smoking status, waist circumference and self-reported TV-viewing. TV-viewing was significantly and positively associated with HOMA (β=0.01 95% CI; 0.004; 0.019, P=0.002) and fasting insulin (β=0.01 95% CI; 0.004; 0.017, P=0.002), independent of objectively measured time estimates and the same confounders as above.

We thereafter examined whether time spent sedentary, at light intensity and at MVPA and TV-viewing predicted insulin resistance at follow-up. Time spent at MVPA was a significant predictor of fasting insulin (β=-0.004, 95% CI; -0.007; -0.00001, P=0.022), and the association approached significance for HOMA (β=0.003, 95% CI; -0.007; 0.000002, P=0.052) independent of baseline phenotype, follow-up time and other confounding factors. Similar to the cross-sectional analyses, time spent sedentary and at light intensity activity were not significantly associated with insulin resistance at follow-up. In contrast to the cross-sectional analyses, TV-viewing did not predict insulin resistance at follow-up (β=-0.0006, 95% CI; -0.007; 0.006, P=0.84 and β=0.00007, 95% CI; -0.006; -0.006, P=0.94, for HOMA and fasting insulin, respectively).

We thereafter examined whether change in MVPA and TV-viewing between baseline and follow-up was associated with insulin resistance. Change in MVPA was significantly and inversely related to change in fasting insulin (β=-0.003, 95% CI; -0.007; -0.0003, P=0.032) and the HOMA score (β=-0.004, 95% CI; -0.008; -0.001, P=0.015) after adjusting for sex, baseline phenotype, age, waist, smoking status, TV-viewing and follow-up time. In contrast, change in TV-
Moderate intensity predicts insulin resistance

viewing was not associated with either fasting insulin ($\beta=0.003$, 95% CI: -0.006; 0.011, $P=0.55$) or the HOMA score ($\beta=0.004$, 95% CI: -0.005; 0.013, $P=0.42$).

Finally, we analysed whether meeting the recommendations of accumulating 30 minutes of MVPA per day at baseline was associated with fasting insulin at follow-up. Meeting this activity guideline was associated with significantly lower mean value for fasting insulin (pmol l$^{-1}$, geometric mean difference between groups = 1.12, [95% CI 1.02, 1.24], $p=0.002$) independent of baseline insulin levels and the same confounders as above. Figure 1 shows fasting insulin levels at follow-up, stratified according to baseline BMI group (normal, overweight, obese) and the dichotomous variable of meeting / not meeting the physical activity guidelines at baseline. BMI group (p for trend=0.004) and meeting activity guidelines (p for trend = 0.050) predicted fasting insulin at follow-up, independent of each other and of baseline fasting insulin, age, sex, smoking status, TV-viewing and follow-up time.

CONCLUSION

Our results suggest that time spent at MVPA is associated with indicators of insulin resistance independent of time spent sedentary, at light intensity activity and TV-viewing. These results were consistent in both cross-sectional and prospective analyses and robust to confounding by adiposity, baseline insulin resistance and other confounding factors. Consistently, an increase in MVPA over one year was associated with improved insulin sensitivity.

This is the first study examining the prospective associations between TV-viewing, objectively measured time spent sedentary and at MVPA with insulin resistance. Previous studies have suggested that objectively measured overall physical activity or PAEE is inversely associated with insulin resistance and other features of the metabolic syndrome (6-13), and in some studies these associations were independent of adiposity and cardio-respiratory fitness (9-11). Evidence is also emerging that TV-viewing and sedentary behaviour is associated with abnormal glucose metabolism, clustered metabolic risk, the metabolic syndrome, and type 2 diabetes (2-5). However, none of these previous studies controlled for objectively measured time spent at MVPA.

In cross-sectional analysis, we observed a significant association between self-reported amount of time watching TV with insulin resistance. However, this association was attenuated in the prospective model suggesting that TV-viewing does not predict insulin resistance independent of objectively measured time spent at MVPA. Indeed, self-reported TV time may be a weak indicator of overall sedentary behaviour. In this data set, TV-viewing was significantly but weakly correlated with light intensity activity but not with objectively measured time spent sedentary or time spent at MVPA. This suggests that TV-viewing do not displace MVPA and that some individuals may combine relatively high levels of physical activity with high levels of TV-viewing. However, TV-viewing may be associated with other unhealthy behaviours which affect obesity and metabolic variables (17).

We recently reported an inverse cross-sectional association between time spent at MVPA with insulin resistance which was independent of PAEE in a middle-aged UK Caucasians in which physical activity was measured with individually calibrated minute-by-minute heart rate monitoring (20). We and others have previously suggested that total daily physical activity (counts/min) measured by accelerometry is a significant determinant of insulin sensitivity, whereas time spent sedentary and at light intensity activity are not (11, 12). These previous cross-sectional
observations corroborate our present prospective observation. This is because time spent at MVPA explains most of the variance in total physical activity (counts/min) ($R^2=0.67$, $p<0.0001$ in the present study), suggesting that activities of moderate intensity, such as brisk walking, are the main contributors to the overall levels of physical activity when measured by accelerometry. Due to issues of multi-collinearity, we were not able to adjust our analyses for total daily physical activity volume (i.e. total counts).

The results from our study should be interpreted with the following limitations in mind. Firstly, our results may only be generalisable to relatively sedentary, overweight, middle-aged, UK whites with a family history of type 2 diabetes. However, given the epidemic increase in overweight and obesity in adult UK men and women (20), and the large proportion of UK adults not being sufficiently active (21), it is likely that our results are generalizable to a larger part of the adult UK population. Secondly, our assessment of visceral adiposity by waist circumference lacks precision compared with more sophisticated measurement techniques such as magnetic resonance imaging and computer tomography. It is therefore possible that some residual confounding by central adiposity may persist. However, measurement error such as this is likely to be small and may be less than in studies where BMI has been used as a measure of adiposity. Thirdly, we used fasting insulin and the HOMA score as markers of insulin resistance. Although these methods are less accurate than the hyperinsulinaemic euglycemic clamp, they serve as valuable surrogates for insulin resistance in normoglycemic individuals (22). The apparent discrepancy between the reduction in time spent viewing TV between baseline and follow-up without a corresponding increase in objectively measured time spent at MVPA is likely explained by the use of different methods when assessing TV viewing (self-report) and time spent at MVPA (accelerometry). It is also plausible that the difference in self-reported time spent TV viewing between baseline and follow-up is explained by misreporting. Finally, although we controlled for many potential confounding factors we cannot rule out the possibility that unmeasured factors such as genotype, birth weight and growth in early life explain the observed associations.

Our study also has some unique strength. The longitudinal design allows statistical control for confounders, measured or unmeasured, which do not change over time. Furthermore, we reduced the potential for recall bias and differential measurement error, which is an unavoidable component of self-reported sedentary behaviour and physical activity, by measuring time spent sedentary and at different intensity levels of activity with accelerometry. Our observations of an independent cross-sectional association between accumulated time spent at MVPA with insulin sensitivity was confirmed in our prospective analysis indicating a causal association. Taken together, it is unlikely the observed associations between time spent at MVPA and insulin resistance is due to measurement error, bias or chance.

The independent association between time spent at MVPA with insulin sensitivity is biologically plausible. The mechanisms by which physical activity may affect insulin sensitivity independent of fat mass include increased glucose transport into skeletal muscle through increases in GLUT-4 protein content and insulin-stimulated trafficking but also through a non-insulin hypoxia-dependent pathway (23). Further, physical activity may increase skeletal muscle capacity to oxidise fat, thereby decreasing the available amount of NEFA to the liver, which may improve hepatic insulin sensitivity (24). In opposite, prolonged time spent sedentary may have distinct physiological effects
comparing with physical activity (25). The relative importance of time spent at different sub-components of physical activity, including time spent sedentary and at MVPA, in association with various metabolic health outcomes need further study. Such studies are not likely to be successful without precise measurements of exposure variables including sub-dimensions of physical activity and different types of sedentary behaviour.

Recent guidelines for health enhancing physical activity state that all adults (18 to 65 years) should engage in at least moderate intensity aerobic physical activity for a minimum of 30 min on five days each week or vigorous-intensity activity for a minimum of 20 min on three days each week (16). Our results support the recommendation of moderate intensity physical activity proposed in these guidelines. However, due to the limited amount of time devoted to vigorous intensity activity in our sample we are not able to comprehensively evaluate the relative importance of vigorous intensity activity on insulin resistance.

In conclusion, time spent at MVPA, objectively measured by accelerometry, predicts insulin resistance, independent of time spent sedentary, at light intensity activity and self-reported TV-viewing. These results highlight the importance of promoting moderate intensity activity such as brisk walking for improving insulin sensitivity and other metabolic risk factors and to prevent type 2 diabetes at least in individuals at high risk of developing this disease.

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a theory-based behavioural intervention to increase physical activity in an at-risk group in
Table 1. Descriptive characteristics (mean and SD, unless otherwise stated) of participants at baseline and follow-up (n=192).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men (n=81)</th>
<th>Follow-up</th>
<th>Women (n=111)</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td></td>
<td>Baseline</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>89.6 (15.4)</td>
<td>90.3 (16.1)</td>
<td>73.3 (13.9)</td>
<td>73.6 (14.3)***</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177.9 (6.3)</td>
<td>177.7 (6.4)</td>
<td>163.5 (6.2)</td>
<td>163.3 (5.8)***</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.3 (4.5)</td>
<td>28.5 (4.7)</td>
<td>27.5 (5.0)</td>
<td>27.7 (5.2)</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td>23.8 (8.3)</td>
<td>24.5 (8.9)</td>
<td>25.9 (9.7)</td>
<td>26.2 (10.0)***</td>
</tr>
<tr>
<td>Fat free mass (kg)</td>
<td>65.9 (8.8)</td>
<td>65.8 (8.6)</td>
<td>47.4 (5.8)</td>
<td>47.4 (5.9)***</td>
</tr>
<tr>
<td>Waist (cm)</td>
<td>101.3 (11.6)</td>
<td>101.6 (12.2)</td>
<td>88.8 (11.2)</td>
<td>89.4 (11.9)***</td>
</tr>
<tr>
<td>Glucose</td>
<td>5.0 (0.8)</td>
<td>5.1 (1.1)</td>
<td>4.8 (0.5)</td>
<td>4.9 (0.5)***</td>
</tr>
<tr>
<td>Insulin (pmol l⁻¹)</td>
<td>56.3 (49.8; 62.3)</td>
<td>63.1 (56.9; 70.0)</td>
<td>48.1 (41.2; 55.2)</td>
<td>48.6 (41.5; 55.5)***</td>
</tr>
<tr>
<td>HOMA†</td>
<td>1.79 (1.56; 2.02)</td>
<td>2.04 (1.84; 2.24)</td>
<td>1.46 (1.24; 1.68)</td>
<td>1.50 (1.29; 1.82)***</td>
</tr>
<tr>
<td>Sedentary (min d⁻¹)</td>
<td>452 (84)</td>
<td>435 (89)</td>
<td>419 (85)</td>
<td>418 (87)***</td>
</tr>
</tbody>
</table>
| Light (min d⁻¹)   | 297 (77)   | 321 (70)  | 310 (74)      |             *
| MVPA (min d⁻¹)    | 29 (16)    | 25 (17)   | 29 (21)       |             |
| TV and Video (h w⁻¹)| 16.8 (9.0) | 14.8 (8.1) † | 20.7 (9.8) | 18.7 (9.4) †*** |
| Current smokers‡  | 21.0%      | 16.0%***  | 16.2%         | 13.6%***†† |

BMI, body mass index; HOMA, homeostasis model assessment; MVPA, moderate and vigorous intensity physical activity

†geometric means and 95% CI, ‡Chi-square for time and sex differences
ANOVA for between sex differences: * P < 0.05; ** P < 0.01; ***P < 0.001
ANOVA for between time differences: † P < 0.05; ††P < 0.01

Table 2. Associations (B-coefficients, 95% CI) between objectively measured time estimates of physical activity and self-reported TV and video viewing at baseline with the HOMA score and fasting insulin in adults with a family history of type 2 diabetes (n=192). The upper part of the table refers to cross-sectional analyses and the lower part to prospective analyses.

<table>
<thead>
<tr>
<th></th>
<th>Baseline HOMA score</th>
<th>P</th>
<th>Baseline fasting insulin</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary (min d⁻¹)</td>
<td>0.0004 (-0.0006; 0.001)</td>
<td>0.42</td>
<td>0.0004 (-0.0006; 0.001)</td>
<td>0.39</td>
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<tr>
<td>Light (min d⁻¹)</td>
<td>0.0001 (-0.001; 0.001)</td>
<td>0.83</td>
<td>0.0002 (-0.001; 0.001)</td>
<td>0.73</td>
</tr>
<tr>
<td>MVPA (min d⁻¹)</td>
<td>-0.004 (-0.008; -0.0001)</td>
<td>0.048</td>
<td>-0.005 (-0.008; -0.001)</td>
<td>0.017</td>
</tr>
<tr>
<td>TV/Video (h w⁻¹)</td>
<td>0.01 (0.004; 0.019)</td>
<td>0.002</td>
<td>0.01 (0.004; 0.017)</td>
<td>0.002</td>
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<table>
<thead>
<tr>
<th></th>
<th>Follow-up HOMA score</th>
<th>P</th>
<th>Follow-up fasting insulin</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary (min d⁻¹)</td>
<td>0.001 (-0.002; 0.0004)</td>
<td>0.21</td>
<td>0.001 (-0.0013; 0.0005)</td>
<td>0.07</td>
</tr>
<tr>
<td>Light (min d⁻¹)</td>
<td>-0.001 (-0.001; 0.0002)</td>
<td>0.16</td>
<td>-0.001 (-0.0013; 0.0002)</td>
<td>0.18</td>
</tr>
<tr>
<td>MVPA (min d⁻¹)</td>
<td>-0.003 (-0.007; 0.000002)</td>
<td>0.052</td>
<td>-0.004 (-0.007; -0.001)</td>
<td>0.022</td>
</tr>
<tr>
<td>TV/Video (h w⁻¹)</td>
<td>-0.001 (-0.007; 0.006)</td>
<td>0.88</td>
<td>0.0002 (-0.006; 0.006)</td>
<td>0.99</td>
</tr>
</tbody>
</table>

HOMA, homeostasis model assessment; MVPA, moderate and vigorous intensity physical activity
Data are adjusted for sex, age, smoking status (current, ex, never), and waist circumference. prospective data are additionally adjusted for baseline phenotypes and follow-up time.
Figure 1. Fasting insulin (geometric mean) at follow up stratified by BMI group (normal weight, overweight, obese) and according to achieving at least 30 minutes of moderate and vigorous intensity physical activity per day (Yes vs. No). Data are adjusted for sex, baseline age, baseline fasting insulin, baseline smoking status, baseline TV viewing and follow-up time (n=192).