

## Low physical activity is a determinant for elevated blood pressure in high cardiovascular risk obstructive sleep apnea

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Dr Pépin has full access to all of the data in the study and he takes full responsibility for the integrity of all of the data and the accuracy of the data analysis, including and especially any adverse effect.

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## ABSTRACT

**Introduction:** Obstructive Sleep Apnea (OSA) is associated with cardiovascular morbidity including hypertension. Beyond the severity of nocturnal hypoxia, others factors such as metabolic abnormalities but also sedentary behaviors and insufficient physical activity may contribute to elevated blood pressure (BP). To clarify the respective role of these factors as determinants of BP in OSA patients, we examined the relationship between BP and anthropometrics, severity of sleep apnea and objectively measured physical activity and sedentary behaviors.

**Methods:** Ninety-five adults presenting with OSA (Apnea-Hypopnea Index (AHI) >10 events/hr) and high cardiovascular risk ( $63.3 \pm 8.8$  years; BMI:  $29.9 \pm 4.9$  kg/m<sup>2</sup>; AHI:  $41.3 \pm 17.5$ /hour; cardiovascular risk SCORE:  $13.5 \pm 3.7$ ) were included. Physical activity and sedentary behaviors were objectively assessed by actigraphy and self-measured home BP monitoring was measured. Logistic regression models adjusted for sex, age and BMI were built to identify the predictors of self-measured morning and evening BP.

**Results:** Physical activity was significantly related to obesity but not with the severity of sleep apnea or sleepiness. Sedentary behaviors were associated with self-measured morning and evening systolic BP ( $r=0.32$ ;  $p=0.0021$ ;  $r=0.29$ ;  $p=0.0043$ ). Steps per day were inversely associated with evening BP ( $r=-0.27$ ;  $p=0.0095$ ). Univariate analysis identified steps per day and time spent in vigorous physical activity as determinants for evening self-measured BP. In multivariate analysis, only steps per day were identified as a significant determinant of evening BP.

**Conclusion:** Physical activity is the major determinant for evening BP in adults with OSA presenting high cardiovascular risk. Our results emphasize the need for lifestyle counseling programs in combination with CPAP to encourage regular physical activity in OSA subjects and obtain better BP control.

## INTRODUCTION

Obstructive sleep apnea syndrome (OSA) has been associated with cardiovascular morbidity and, in particular, hypertension.<sup>1, 2</sup> The repetitive occurrence of apneas and hypopneas with the associated intermittent hypoxia sequence causes acute surges in blood pressure, sleep fragmentation, and chronic sympathetic activation that ultimately lead to sustained hypertension.<sup>3</sup> A large body of evidence from animal models, intermittent hypoxia exposure of healthy humans<sup>4</sup> and epidemiological studies support an independent role of OSA in the pathogenesis of daytime hypertension.<sup>2, 5, 6</sup> However, it has been shown that continuous positive airway pressure (CPAP), the first line therapy of OSA has a limited effect on blood pressure control<sup>7, 8</sup> and the size of the effect is highly related to the duration of nightly CPAP usage.<sup>9, 10</sup> This suggests that in these frequently obese and comorbid OSA patients, the severity of abnormalities during sleep is only one of the numerous factors explaining elevated daytime blood pressure.

Lack of physical activity (PA) is an established modifiable risk factor for cardiovascular disease and premature mortality.<sup>11, 12</sup> Most studies examining PA and cardiovascular risk are based on subjective questionnaires and the majority of surveys have reported higher rates of elevated blood pressure in inactive vs. active individuals.<sup>13, 14</sup> Recent evidence recognises that time spent in self-reported sedentary behaviors is a unique and independent risk factor for cardiovascular disease.<sup>15</sup> Previous studies have also reported an association between sedentary behaviors and increased risk of hypertension.<sup>16, 17</sup> OSA severity has been associated with self-reported lack of exercise and potentially impairs exercise performance.<sup>18</sup>

Sleep duration is another modifiable risk factor that may impact blood pressure (BP), PA and sedentary behaviors. Short-term sleep deprivation studies suggest that acute sleep deprivation increases BP.<sup>19, 20</sup> Furthermore, a relationship between habitual sleep duration and BP<sup>21</sup> and an inverse relation between sleep duration and body mass index (BMI)<sup>22, 23</sup> have

been demonstrated. Hypertension in short sleepers may then also be favoured by the development of overweight.<sup>24, 25</sup> A recent study has shown that short-term sleep loss reduces daytime overall spontaneous physical activity and shifts the intensity of physical activity toward lower levels under free-living conditions.<sup>26</sup> Accordingly, alterations in sleep quantity and quality during OSA and the associated daytime sleepiness and fatigue may be reasons for reduced physical activity and increased sedentary behaviours.<sup>27</sup> However, there is limited data regarding objective measures of different intensities of physical activity and sedentary behaviors and their relation to cardiovascular risk factors and blood pressure in OSA patients.

We hypothesized that daytime sleepiness, fatigue and obesity frequently exhibited by OSA patients would lead to lower levels of physical activity and increased sedentary behavior which, in turn, can negatively impact BP. The aim of the present study was to assess the predictors of elevated BP in OSA patients with high cardiovascular risk. Accordingly, we examined the relationship between BP and anthropometrics, severity of sleep apnea and objectively measured physical activity and sedentary behaviors.

## 2. METHODS

### 2.1 Study design and participants

Ninety five adults with OSA were prospectively included. Inclusion criteria were the following: 18-85 year old men and women allowing a representation of OSA adults that are active in the workforce or retired and that are capable of demonstrating at least light physical activity, BMI < 40 kg/m<sup>2</sup>, OSA diagnosed with polysomnography or polygraphy, cardiovascular score > 5 %<sup>28</sup> or secondary prevention with a past history of cardiovascular disease (transient ischemic attack, stroke; cerebral haemorrhage, myocardial infarction, angina, coronary revascularization, arteriopathy, aortic aneurism). Subjects were recruited from 13 centers across France. Mean recruitment per center was 8 subjects. Stratification was carried out to adjust the models with regards to the recruiting center. Non-inclusion criteria were the following: central sleep apnea syndrome, cardiovascular score < 5% in primary prevention<sup>28</sup>, cardiac failure, history of hypercapnic chronic respiratory failure, incapacitated patients in accordance with article L 1121-6 of the French public health code or patients taking part in another clinical trial. The study protocol was approved by the ethical committee (CPP Sud Est V, 09-PROR-1). All of the subjects provided written informed consent to participate in the study. The different assessments in this study corresponded to a baseline evaluation before being included in a prospective randomized controlled trial targeting the efficiency of a telemedicine program in addition to standard CPAP treatment (Clinical Trials registration # NCT01226641).

### 2.2 Dyspnea and fatigue questionnaires

Levels of fatigue over the past 6 months were measured using the 11-item Chalder Fatigue Scale<sup>29</sup>, which consists of four items for mental fatigue and seven items for physical fatigue. Dyspnea was evaluated with the Sadoul questionnaire.<sup>30</sup>

### 2.3 Cardiovascular score

Ten-year risk of fatal cardiovascular event (SCORE calculation for European countries: Systematic Coronary Risk Evaluation Project) was calculated.<sup>28</sup> For data analysis, cardiovascular SCORE was automatically set at 15% if participants were in secondary prevention (i.e. suffered a cardiovascular event in the past).

### 2.4 Blood pressure and heart rate measurements

Clinic BP was measured in the lying position by mercury sphygmomanometer on two occasions (two consecutive days), with three measurements spaced by one minute on each occasion, according to European guidelines on hypertension.<sup>31</sup> Clinic heart rate was measured by pulse palpation (30 seconds) after the third measurement in the lying position. The following clinic parameters were assessed: systolic BP (SBP), diastolic BP (DBP) and HR. Office hypertension was defined as a mean (average of the three measurements at each of the two office sessions) office SBP  $\geq$  140 mmHg and/or a mean office DBP  $\geq$  90 mmHg.<sup>31</sup>

Self-measured home BP monitoring was performed on three consecutive days using validated fully automated electronic device Omron 705CP® (Omron Corp., Tokyo, Japan). Participants were trained to use this device and they were instructed to take three measures in the morning (between awakening and breakfast) and three measures in the evening (between dinner and bedtime) after 5 minutes sitting at rest and with one-minute intervals between measurements. A form was supplied to the participants to report all self-measured BP values. For each subject, mean of morning and evening measures was made. The circumference at the midpoint of the upper arm was measured and a normal cuff was used for circumferences below 32 cm; otherwise a large cuff was used.

Target blood pressures for home readings were based on the then current UK NICE guidelines for hypertension and diabetes, adjusted down by 10/5 mm Hg in accordance with the recommendations of the British Hypertension Society (home readings tend to be lower than

office readings). Target values were therefore 135/85 mm Hg for subjects without diabetes and 125/80 mm Hg for subjects with diabetes.<sup>32, 33</sup>

## 2.5 Sleep studies

OSA diagnosis was obtained by full polysomnography or by simplified polygraphy without electroencephalogram (EEG) recordings. Sleep was scored manually according to standard criteria. Polysomnography used continuous acquisition of the following recordings: electro-oculogram (EOG; 3 channels), electro-encephalogram (EEG; 3 channels), electromyogram (EMG; 1 channel) and electrocardiogram (ECG; 1 channel). Airflow was measured using nasal pressure associated with the sum of oral and nasal thermistor signals. Respiratory effort was monitored with abdominal and thoracic bands. An apnea was defined as a complete cessation of airflow for at least 10 s and a hypopnea as a reduction of at least 50% in the nasal pressure signal or a decrease between 30% and 50% associated with either oxygen desaturation of at least 4% or EEG arousal. Apneas were classified as obstructive, central or mixed according to the presence or the absence of respiratory effort. The criterion for sleep apnea in this study was an apnea–hypopnea index (AHI)  $\geq 10$  events per hour of sleep.

## 2.6 Accelerometer data collection and analysis

Daily physical activity was assessed using an activity monitor (Sensewear Pro2 armband, SWA; Body Media, Pittsburgh, PA, USA).<sup>34</sup> The Sensewear Pro2 armband contains accelerometers that sense movement in two planes, a galvanic skin sensor, a temperature sensor, and a near-patient temperature sensor. Subjects wore the activity monitor for the same period as blood pressure monitoring (i.e. 72 hours) allowing an estimate of mean daily physical activity by averaging data over 1 weekday and the weekend.

The intensity of activity for each minute of wear time was calculated and expressed using metabolic equivalents (METs) to determine daily time spent in sedentary, light, or moderate-



to-vigorous activity. Sedentary behavior was defined as activities resulting in energy expenditure  $<1.5$  METs, which is equivalent to sitting.<sup>35</sup> Light-intensity PA was defined as 1.5–3 METs, moderate PA as 3–6 METs, vigorous PA as 6–9 METs and very vigorous  $> 9$  METs. This device also allows estimating sleep duration.

## 2.7 Statistical analysis

Continuous data were presented as mean  $\pm$  standard deviation (SD) and categorical data as percentages (%). Variables with over 15% of missing values weren't included in the analysis. Colinearity was assessed with Pearson's or Spearman's coefficient (depending on validation of normality distribution) or Cramer's V2. Normality of the data was verified using Skewness and Kurtosis' tests.

Relationship between self-measured blood pressure and physical activity was analyzed with logistics regressions. A SBP  $\geq 135$  mmHg or a DBP  $\geq 85$  mmHg, for non diabetic subjects, and a SBP  $\geq 125$  mmHg or a DBP  $\geq 80$  mmHg for diabetic subjects were considered as high levels of blood pressure.<sup>32, 33</sup>

Two sex-, age-, BMI-adjusted linear regression models, stratified by recruiting centers were built; one for self-measured morning blood pressure and the other, for self-measured evening blood pressure. In the univariate logistic regression, when a continuous variable was not log-linear, it was recoded by creating a new variable from the quartiles or the median depending on the quality of information. Independent parameters were included in the multivariate model when significance was  $\leq 0.1$  in the univariate model. Missing values were replaced by the median for continuous data and by the most frequent value for categorical data. A backward selection was employed for multivariate model.

Results were considered statistically significant when p-value was  $<0.05$ . Statistical analysis was performed with SAS 9.1.3 package (SAS Institute, Cary, NC, USA).

### 3. RESULTS

#### 3.1 Study participants characteristics

Subjects' characteristics are presented in Table 1. Subjects' mean age was  $63.3 \pm 8.8$  years, they were predominantly male (83.2%) and overweight or obese (BMI of  $29.9 \pm 4.9$  kg/m<sup>2</sup>). By definition, subjects had high 10-year cardiovascular risk scores ( $13.5 \pm 3.7\%$ ). They exhibited moderate to severe apnea+hypopnea index ( $41.3 \pm 17.5$ /hour) with a significant amount of nocturnal hypoxia (CT90:  $14.64 \pm 19.73\%$ ). Sleepiness as measured by the Epworth Sleepiness Scale was at the upper limit of the normal range ( $8.0 \pm 4.4$ ). Sleep duration estimated at home on three different nights by accelerometer was  $353.7 \pm 85.1$  minutes ( $5.9 \pm 1.4$  hours) (Table 2).

#### 3.2 Physical activity and sedentary behaviors

Average number of steps per day (SPD) was  $7393 \pm 3545$  and mean daily energy expenditure was  $2622.6 \pm 515.9$  kcal (Table 2). Average daily METs levels were  $1.32 \pm 0.28$ , which is significantly lower than 1.5 (i.e., the cut-off point below which sedentary behavior is defined).<sup>35</sup> Time spent in sedentary behaviors, light physical activity and moderate-to-vigorous physical activity were  $736.3 \pm 138.6$ ,  $224.1 \pm 90.9$  and  $98.0 \pm 91.7$  minutes, respectively ( $12.7 \pm 2.3$ ;  $3.7 \pm 1.51$  and  $1.6 \pm 1.5$  hours, respectively) (Table 2).

#### 3.3 Association between obesity and sleep apnea severity and physical activity and sedentary behaviors

Body mass index was inversely correlated with SPD ( $r=-0.2781$ ;  $p=0.0073$ ) (Figure 1) and daily METs ( $r=-0.4287$ ;  $p<0.0001$ ). SPD did not correlate with sleepiness or other indices of OSA severity (Figure 2: panel A: ESS and panel B: mean nocturnal SaO<sub>2</sub>).

### 3.4 Association of physical activity and sedentary behaviors with BP

Total energy expenditure was inversely correlated with office diastolic BP ( $r=-0.2185$ ;  $p=0.0374$ ). SPD were inversely correlated with evening self-measured systolic BP ( $r=-0.2690$ ;  $p=0.0095$ , figure 3A) but not morning self-measured blood pressure. Time spent in sedentary behaviors (0–1.5 METs) was positively associated with self-measured morning and evening SBP (figure 3B) and DBP ( $r=0.315$ ,  $p=0.0021$ ;  $r=0.2807$ ,  $p=0.0064$  and  $r=0.293$ ,  $p=0.0043$ ;  $r=0.268$ ,  $p=0.0093$ , respectively).

### 3.5 Determinants of blood pressure

#### Morning BP

Univariate analysis, adjusted for age, sex and BMI and stratified for recruiting center, identified cardiovascular SCORE and cumulative time spent with  $\text{SaO}_2$  below 90% as significant determinants for morning self-measured BP (Table S1). In multivariate analysis, secondary prevention was associated with morning self-measured BP in the normal range (OR, 0.222; 95% CI, 0.053-0.925;  $p=0.039$ ) whereas alcohol consumption was associated with higher values of self-measured BP (OR, 10.427; 95% CI, 2.362 - 46.041;  $p=0.0020$ ).

#### Evening BP

In univariate analysis, cardiovascular risk SCORE, cumulative time spent with  $\text{SaO}_2$  below 90%, number of steps per day and time spent in very vigorous physical activity ( $> 9$  METs) were linked with evening self-measured BP in the normal range (Table S1). On the other hand, time spent in sedentary behaviors, BMI, type 2 diabetes, high scores for Sadoul and Chadler scales were identified as determinants of elevated evening self-measured BP. Smoking was not identified as a predictor of elevated morning or evening BP.

Multivariate analysis identified cardiovascular score above 15% (OR, 0.199; 95% CI, 0.041-0.957;  $p=0.0439$ ) and number of steps per day (for  $6932.50 < \text{SPD} < 10012$  vs  $< 4974.50$  SPD: OR, 0.147; 95% CI, 0.024-0.892;  $p=0.0371$ ) and (for  $\text{SPD} \geq 10012$  vs  $<$

4974.50: OR, 0.143; 95% CI, 0.024 - 0.859;  $p=0.0335$ ) as significant determinants of evening self-measured BP in the normal range = (Figure 4). Presence of diabetes was associated with elevated evening self-measured BP (OR, 7.37; 95% CI, 1.71 -31.73,  $p=0.0073$ ).

#### 4. DISCUSSION

In adults with OSA presenting high cardiovascular risk, physical activity is reduced and far from consensus recommendations for optimal health. The level of physical activity is significantly related to the degree of obesity but not linked with the severity of sleep apnea or sleepiness. The main finding of our study was that steps per day and sedentary behaviors are the most important predictors of evening self-measured BP. Thus, in individuals with OSA, daily physical activity impacts BP levels but with a different magnitude in the morning and evening. Self-measured BP measures were performed, as this type of measure seems to have a stronger predictive power for future cardiovascular events.<sup>36</sup> Both morning and evening home BP have been shown to be positively associated with the incidence of stroke<sup>36, 37</sup>, indicating that evening BP has clinical relevance. Thus in the present study, we created two univariate models: for morning and evening BP.

Our study is the first having examined the relationship between objective measures of physical activity and sedentary behaviors and home self-measured BP in high cardiovascular risk OSA subjects. Only two previous studies in the field have reported interesting but more limited data on higher energy expenditure during sleep<sup>38</sup> or mean activity in arbitrary units.<sup>39</sup> Interestingly physical activity was not increased by CPAP treatment suggesting that OSA per se is not the main contributor to reduced BP.<sup>39</sup> In our study, we measured physical activity patterns with an accelerometer validated in healthy subjects<sup>40</sup> and in diabetics<sup>34</sup>. This device, which has also been recently validated in OSA during sleep<sup>38</sup>, is considered one of the most reliable means of estimating physical activity and its patterns in free living conditions.<sup>41, 42</sup> In a recent study comparing the validity of six activity monitors, the SenseWear Armband (a biaxial monitor) was one of the two most valid monitors during standardized physical activities.<sup>43</sup> A major strength of our study was to provide objective measures of sedentary behaviors concurrently to home self-measurement of BP. The recommended duration for such a BP assessment is 72 hours<sup>44</sup> and we decided to correlate physical activity and BP

measurement in this time window. We do however acknowledge that averaging measures from a 7-day period would have been ideal. Another strength and originality is that BP was assessed by home self-measurement of BP which is now accepted as a better predictor of target organ damages and even incident cardiovascular events compared to office measurements of BP.<sup>45</sup>

Study participants were representative of a typical middle-aged, male OSA population with co-morbidities.<sup>5, 46</sup> Sleepiness for the whole group was at the upper limit of the normal range. OSA patients also suffering from associated cardiovascular diseases<sup>47</sup> or diabetes<sup>48</sup> tend to not complain from sleepiness but rather of fatigue or dyspnea. Only 25% of the included subjects reached recommended levels of physical activity, (i.e. 10,000 steps per day). There was an inverse correlation between the number of steps per day and BMI consistent with the well documented inverse relationship between physical activity and weight gain.<sup>49</sup> A previous study that assessed physical activity by questionnaires found that physical activity was a stronger predictor of perceptions of fatigue and energy than OSA severity<sup>50</sup>. These results contrast with our study, in which subjective sleepiness was not associated with spontaneous physical activity. As questionnaires are known to be subject to widely varying bias<sup>51</sup>, our study has the advantage of providing objectively-measured spontaneous physical activity in individuals with OSA.

### **Blood pressure: respective role of physical activity and OSA**

Approximately, sixty percent of individuals with OSA exhibit daytime hypertension.<sup>52</sup> The dose-response relationship between the severity of OSA and incident hypertension has been clearly demonstrated both in the general population<sup>2</sup> and in clinical cohorts<sup>1</sup>. OSA is now acknowledged as a cause of hypertension in European and American guidelines on hypertension management.<sup>31, 53</sup> However, it has been recently shown that CPAP intervention only has a limited effect on BP control with pooled mean changes of -2.46 mm Hg in systolic BP and -1.83 mm Hg in diastolic 24-hour BP.<sup>7</sup> This suggests that OSA per se, which is

frequently associated with obesity, is only one of the many potential contributors to uncontrolled BP. In the multivariate analysis of morning self-measured BP, only alcohol consumption and diabetes were identified as determinants for hypertension. Secondary cardiovascular prevention was associated with lower morning self-measured BP. The relation between hypertension and excess alcohol consumption, and diabetes is well established.<sup>54</sup> Among the potential contributors to elevated BP is sedentary behaviors, which has emerged as an independent risk factor for cardiovascular disease.<sup>55</sup> In the present study, sedentary behaviors were positively associated with self-measured morning and evening SBP and DBP. Furthermore, univariate analysis identified time spent in sedentary behaviors as a determinant of elevated evening self-measured BP. Our results are supported by a prospective cohort study in which self-reported total sedentary behaviors were directly associated with a higher risk of incident hypertension.<sup>17</sup>

In our study, multivariate analysis identified steps per day as a determinant of lower evening self-measured BP. A recent population-based study showed that leisure activity at different life stages was associated with lower SBP and DBP in mid-adulthood by about 1–2 mmHg and with reduced risk of hypertension by about 23% (active vs. non-active), though this reduction was influenced by age.<sup>56</sup>

### **Study limitations**

This study could have benefited from a control group, which would have allowed establishing whether the same determinants impact BP in individuals presenting high cardiovascular risk without OSA. It would have been interesting to measure dietary patterns of participants in the present study to establish whether or not certain dietary habits contributed to elevated BP as several epidemiological surveys have suggested that diet is an important factor in modulating blood pressure.<sup>57</sup>

## **Practical implications in the management of OSA patients**

In our final multivariate model, only steps per day were identified as a determinant for lower evening self-measured BP. Steps per day can be measured simply with a pedometer, which is far less expensive than the accelerometer we used in the present study. Emergent body of evidence suggests that pedometer-determined physical activity is related to a number of cardiovascular health outcomes.<sup>58</sup> Pedometers may prove a more financially viable option to increase physical activity levels and concomitantly reduce sedentary behaviour. Simpler recommendations such as increasing SPD, ideally to 10,000/day, can be easily integrated in daily life activities (transport, domestic tasks) and should be implemented as a combined therapy with CPAP treatment. Moreover, as the effects of CPAP on cardiometabolic markers are controversial<sup>59-61</sup>, any increase in physical activity will positively impact on lipid and glucose metabolism abnormalities.

Thus, for individuals with OSA presenting high cardiovascular risk, a combined approach integrating CPAP and lifestyle interventions including physical activity programs would improve BP control and in turn potentially reduce mortality. Regular physical activity can also enhance the effects of CPAP therapy, as it has been associated with reduced incidence and severity of sleep-disordered breathing in longitudinal and cross-sectional studies.<sup>62-65</sup>

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## FIGURE AND TABLE LEGENDS

### FIGURES

**Figure 1.** Correlation between body mass index (BMI) and steps per day (SPD). The dotted line represents the recommended level of steps per day for optimal health.<sup>58</sup>

**Figure 2.** Epworth sleepiness score (A) and mean nocturnal oxygen saturation (SaO<sub>2</sub>) plotted against steps per day (B).

**Figure 3.** Correlation between steps per day and self-measured evening SBP (A). Correlation between time spent in sedentary behaviour and self-measured evening SBP (B).

**Figure 4.** Multivariate analysis for self-measured evening blood pressure. Odds ratios and 95% Confidence intervals are depicted.

### TABLES

**Table 1.** Anthropometric, clinical and polysomnographic characteristics.

**Table 2.** Physical activity measurements.

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**Table 1.** *Anthropometric, clinical and polysomnographic characteristics.*

	Mean $\pm$ SD (min-max) (n=95)
<b>Clinical data</b>	
Age (years)	63.3 $\pm$ 8.8 (40.0 – 82.0)
Gender (men, %)	79 (83.2%)
BMI (kg/m <sup>2</sup> )	29.9 $\pm$ 4.9 (21.0 – 45.0)
BMI < 25 kg/m <sup>2</sup> (n, %)	12 (12.6)
25 < BMI < 30 kg/m <sup>2</sup> (n, %)	40 (42.1)
30 < BMI < 35 kg/m <sup>2</sup> (n, %)	29 (30.5)
35 < BMI < 40 kg/m <sup>2</sup> (n, %)	11 (11.6)
BMI > 40 kg/m <sup>2</sup> (n, %)	3 (3.1)
Office systolic blood pressure (mm Hg)	138.4 $\pm$ 18.4 (108.0 – 200.0)
Office diastolic blood pressure (mm Hg)	80.7 $\pm$ 12.4 (57.0 – 120.0)
Type 2 diabetes (%)	34.0
Smoker (never:current:ex)	32 (33.7%): 15 (15.8%): 48 (50.5%)
Alcohol (units/day)	1.2 $\pm$ 1.7 (0 – 7.0)
Cardiovascular risk score (%)	13.5 $\pm$ 3.7 (5.0 – 27.6)
Patients in secondary prevention (number, %)	57 (60%)
<b>Home Self-measured blood pressure</b>	
Morning systolic blood pressure (mm Hg)	135.2 $\pm$ 13.7 (105.9 – 164.0)
Morning diastolic blood pressure (mm Hg)	81.3 $\pm$ 9.7 (60.8 – 122.1)
Evening systolic blood pressure (mm Hg)	130.5 $\pm$ 15.3 (102.3 – 174.9)
Evening diastolic blood pressure (mm Hg)	77.1 $\pm$ 9.5 (46.8 – 105.0)
<b>Lipid profile</b>	
Total cholesterol (mmol.L <sup>-1</sup> )	4.71 $\pm$ 1.13 (2.66 – 7.79)
HDL (mmol)	1.29 $\pm$ 0.53 (0.37 – 4.14)
LDL (mmol)	2.56 $\pm$ 1.06 (0.81 – 5.33)
Fasting glucose (g/L)	1.13 $\pm$ 0.32 (0.51 – 2.63)
<b>Epworth Sleepiness Score</b>	8.0 $\pm$ 4.4 (0 – 20.0)
<b>Chadler Fatigue Scale</b>	
Physical symptoms	16.15 $\pm$ 3.63 (7.0 – 28.0)
Mental symptoms	9.05 $\pm$ 1.94 (5.0 – 15.0)
<b>Sadoul dyspnea score</b>	41.34 $\pm$ 17.50 (0 – 5.0)
<b>Sleep studies</b>	
AHI (number of events/h of sleep)	41.34 $\pm$ 17.50 (10.2 – 98.6)
Mean nocturnal SaO <sub>2</sub> (%)	92.40 $\pm$ 2.35 (83.0 – 96.0)
Minimum nocturnal SaO <sub>2</sub> (%)	78.46 $\pm$ 8.46 (49.0 – 92.0)
CT 90 (%)	14.64 $\pm$ 19.73 (0 – 85.0)

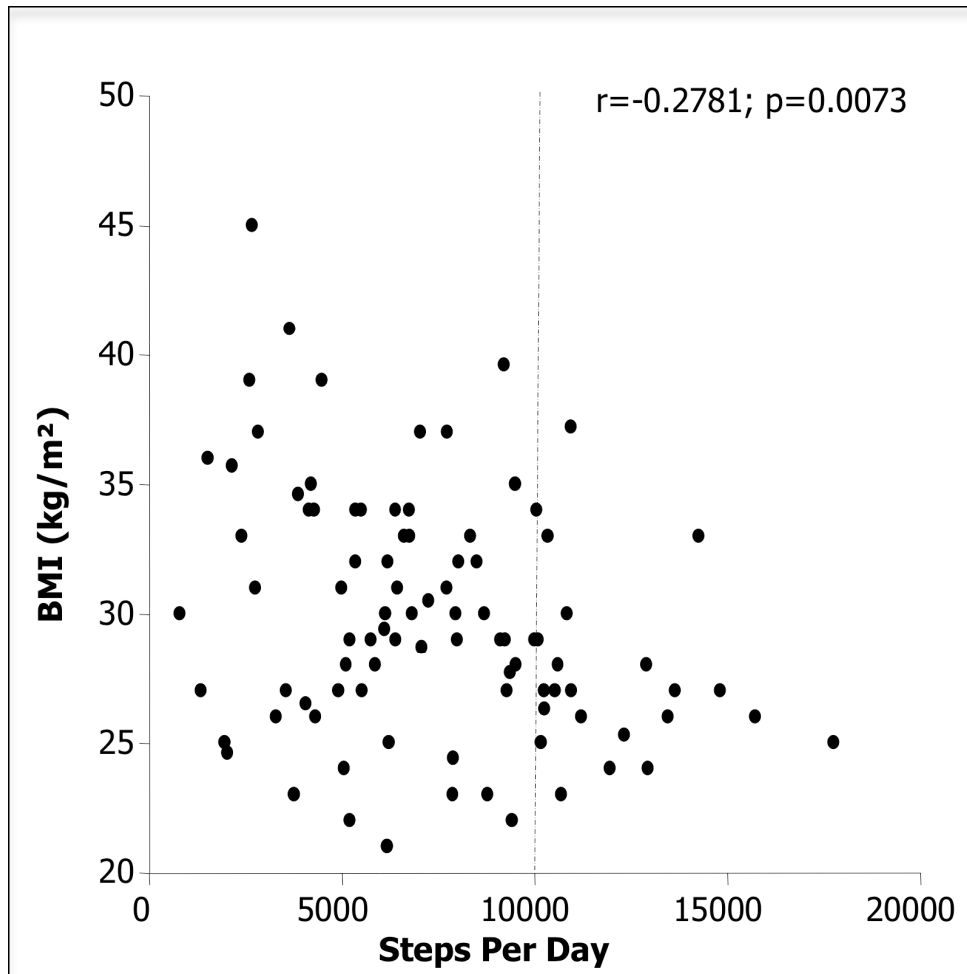
AHI: apnea hypopnea index; n: number of subjects; CT 90 (%): cumulative time spent with SaO<sub>2</sub> below 90% (% of time of recording) SaO<sub>2</sub>: oxygen saturation.

Table 2. *Physical activity measurements.*

	Mean $\pm$ SD (min-max) (n=95)
<b>Energy expenditure (kcal)</b>	2622.59 $\pm$ 515.86 (1625.0 – 3892.0)
<b>Steps per day (number)</b>	7392.99 $\pm$ 3544.78 (801.0 – 17761.0)
<b>Average METs</b>	1.32 $\pm$ 0.28 (0.80 – 2.40)
<b>Exercise intensity</b>	
Total time in sedentary behaviors (0 – 1.5 METs, min)	736.3 $\pm$ 138.6 (342.0 – 1062.0)
Total time in light physical activity (1.5 – 3 METs, min)	224.1 $\pm$ 90.9 (48.0 – 505.0)
Total time in moderate physical activity (3 – 6 METs, min)	95.07 $\pm$ 86.47 (0 – 416.0)
Total time in vigorous physical activity (6 – 9 METs, min)	2.89 $\pm$ 7.79 (0 – 59.0)
Total time in very vigorous physical activity (> 9 METs, min)	0.05 $\pm$ 0.37 (0 – 3.0)
<b>Sleep duration (min)</b>	353.71 $\pm$ 85.13 (120.0 – 516.0)
<b>Total time lying down (min)</b>	453.34 $\pm$ 86.61 (213.0 – 720.0)

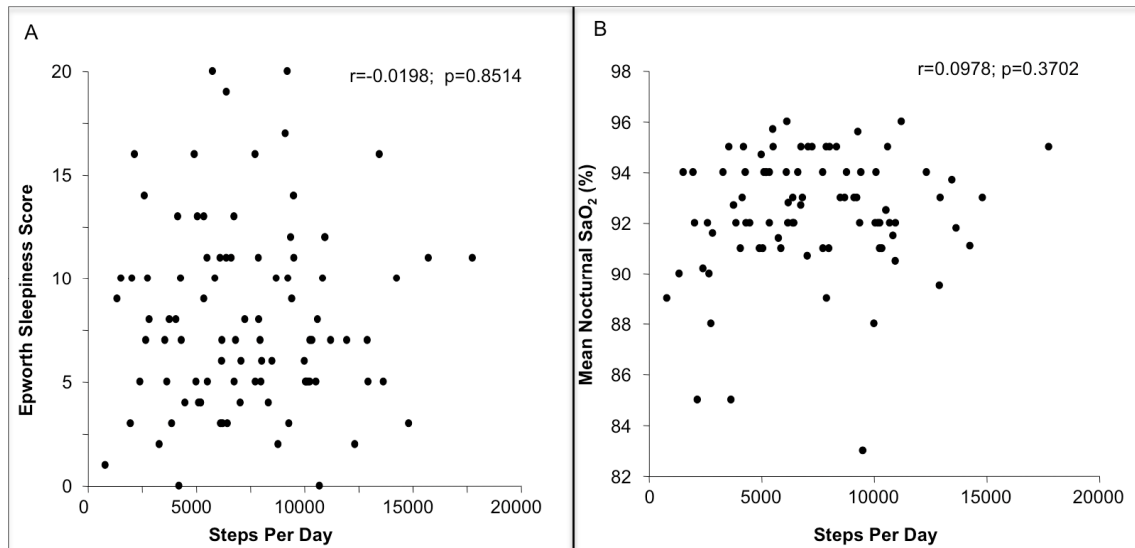
METs: metabolic equivalent.



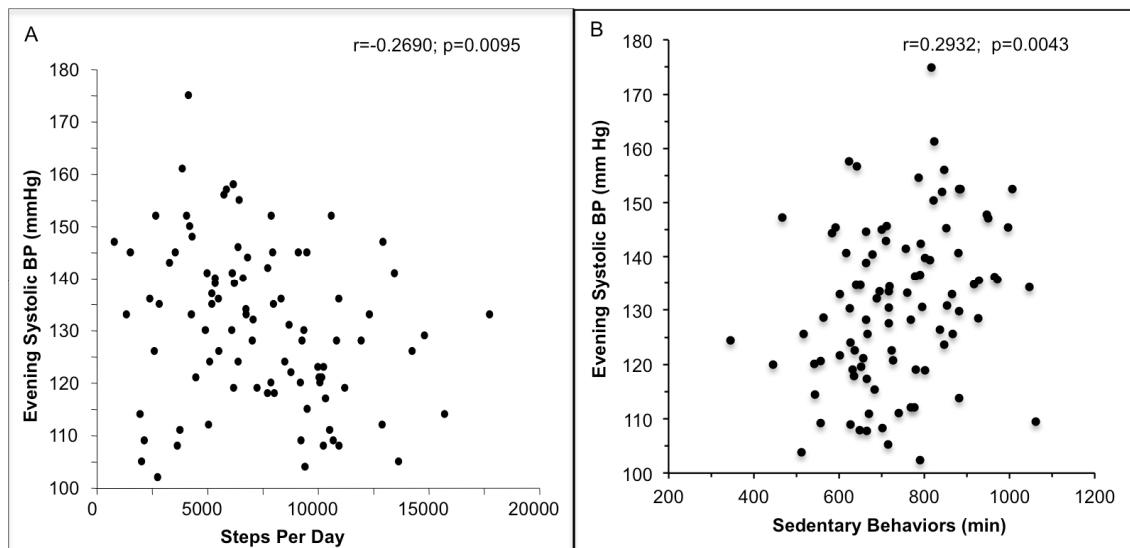


**Figure 1.** Correlation between body mass index (BMI) and steps per day (SPD). The dotted line represents the recommended level of steps per day for optimal health (Tudor-Locke, 2010).

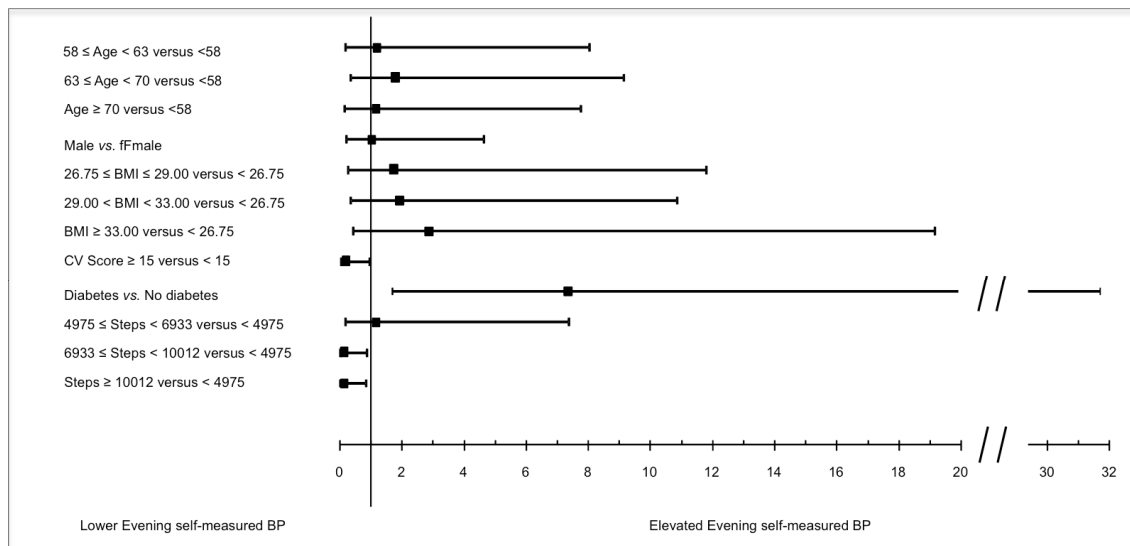




**Figure 2.** Epworth sleepiness score (A) and mean nocturnal oxygen saturation ( $\text{SaO}_2$ ) plotted against steps per day (B).



**Figure 3.** Correlation between steps per day and self-measured evening SBP (A). Correlation between time spent in sedentary behaviour and self-measured evening SBP (B).



**Figure 4.** Multivariate analysis for self-measured evening blood pressure. Odds ratios and 95% Confidence intervals are depicted.