References


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Relationship between sedentary behaviour, physical activity, muscle quality and body composition in healthy older adults

Sedentary behaviour (SB), defined as time spent sitting or lying, has been shown to be a major modifiable risk factor for chronic disease, disablement and frailty [1] independently physical activity levels (PA) [2, 3]. Time spent sitting or lying affects muscle physiology [4], is thought to accelerate sarcopenia [5], and to be a determinant driver of the obesity epidemic [6]. These two effects of SB: obesity and low muscle strength appear to potentiate each other to increase risk of disablement and frailty in older adults [7].
Interventions promoting a decrease in sedentary time and an increase in energy expenditure are advocated for the treatment and prevention of sarcopenia [8–10] and obesity, but studies have shown that programmed PA is accompanied by a spontaneous increase in sedentary periods both before and after PA [11] as a strategy to maintain the energy. Therefore efforts to maintain muscle strength and expend energy might be counteracted by the effects of increased prolonged periods of SB with potential fat gain [12, 13].

The aim of this study was to investigate the relationship between patterns of SB, habitual PA, body composition and muscle strength in older men and women using objectively measured data in free-living conditions.

Methods

The study was based on a cross-sectional design with a convenience sample of (n = 50) healthy older adults volunteers (n = 16 men, age = 79.0 ± 3.6 years and n = 14 women, age = 79.3 ± 3.4 years) (see Table 1 for physical characteristics and Table A1 in Appendix A in the Supplementary data available in Age and Ageing online for medication and functional capacity data). They were defined as healthy on the basis of their responses to previously published health selection criteria [14] (given in Table A2 in Appendix 1). None was engaged in any form of physical training. All procedures received local ethical committee approval. Informed written consent was obtained from the volunteers prior to their participation in the study. The study conformed to the standards set by the Declaration of Helsinki.

Body composition was measured using dual X-ray absorptiometry (DEXA Hologic Discovery) and lower limb extensor power (LLEP) using the Nottingham Power Rig [10]. Muscle mechanical quality (MQ) was defined as LLEP/lower limb fat free mass (W kg−1).

PA and SB were recorded continuously over a 7-day period using an activPAL™ activity monitor [11], which has been shown to be valid, accurate and sensitive in older adults [15, 16].

SB, i.e. total and pattern of sedentary time was measured by extracting bouts of time spent seated or lying from the activPAL™ records. The total sedentary time was computed by summation of all the bouts and the pattern (fragmentation F) calculated as the ratio of the number of sedentary bouts divided by the total sedentary time [11].

PA was measured as the percentage time spent walking and the percentage time spent walking at a low (cadence <93 step/min), moderate and vigorous intensity (cadence > 124 step/min). These intensity levels were defined by the MET compendium [17] (low <3MET, vigorous >6 MET) and converted to thresholds of walking cadence using a previously reported relationship between cadence and walking intensity [18].

Associations between total sedentary time and F with body composition and leg power were measured using Pearson’s correlation analysis and significance level set at 0.05. Using a generalised linear model, we investigate the effect of sedentary time on muscle quality taking into account that interruptions of sedentary periods occur with different intensities of PA (low, moderate, vigorous). In this model the muscle quality was the dependent variable and sedentary fragmentation considered as a predictor. Total time spent walking at different intensities (low, moderate and vigorous) were entered into the model in a step-wise fashion.

Results

All outcome measures were normally distributed (P > 0.05 in Kolmogorov Smirnov test) except for the percentage of time spent in vigorous activity (P = 0.010) which appeared to be log-normally distributed. A log transformation was applied to this variable for subsequent analysis.

For women, no significant correlations were found between total sedentary time and percentage body fat (r = 0.382; P = 0.276), lower limb body fat (r = 0.117; P = 0.748) LLEP (r = 0.151; P = 0.678) and MQ (r = 0.186; P = 0.607). Significant and strong negative correlations were found between sedentary time fragmentation (F) and percentage body fat (r = −0.847; P = 0.002) and lower limb fat mass (r = −0.806; P = 0.005) but not between F and LLEP (r = −0.158; P = 0.663) or MQ (r = −0.465; P = 0.176).

For men total sedentary time was significantly associated with body fat (r = 0.548; P = 0.042), lower limb fat mass (r = 0.765; P = 0.001), LLEP (r = 0.739; P = 0.003) and MQ (r = 0.607; P = 0.021). Significant negative correlations were found between sedentary time fragmentation and percentage body fat (r = −0.600; P = 0.023), lower limb fat

Table 1. (a) Mean (SD) % body fat, lower limb composition, lower limb extensor power (LLEP), muscle mechanical quality (MQ), sedentary behaviour and physical activity variables

<table>
<thead>
<tr>
<th>Gender</th>
<th>Percentage of body fat</th>
<th>Lower limb fat free mass (kg)</th>
<th>Lower limb fat mass (kg)</th>
<th>LLEP (W)</th>
<th>MQ (W kg⁻¹)</th>
<th>Total sedentary time (h)</th>
<th>Fragmentation of sedentary time (F) (bouts/sedentary hours)</th>
<th>Total walking time (h)</th>
<th>Time spent walking at low intensity (h)</th>
<th>Time spent walking at moderate intensity (h)</th>
<th>Time spent walking at vigorous intensity (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>31.6 (7.7)</td>
<td>6.0 (0.9)</td>
<td>3.9 (1.2)</td>
<td>64.3 (26.1)</td>
<td>10.6 (3.8)</td>
<td>16.8 (1.6)</td>
<td>3.3 (0.4)</td>
<td>1.8 (0.5)</td>
<td>1.4 (0.4)</td>
<td>0.3 (0.2)</td>
<td>0.1 (0.02)</td>
</tr>
<tr>
<td>Men</td>
<td>22.9 (3.8)</td>
<td>8.5 (1.1)</td>
<td>2.6 (0.7)</td>
<td>129.9 (41.7)</td>
<td>15.3 (4.8)</td>
<td>17.7 (1.8)</td>
<td>2.6 (0.8)</td>
<td>1.7 (0.9)</td>
<td>1.4 (0.4)</td>
<td>0.3 (0.4)</td>
<td>0.1 (0.02)</td>
</tr>
</tbody>
</table>

Values of lower limb composition, LLEP and MQ averages for left and right legs.
Aim: to characterise the association between sedentary time (SB), habitual physical activity (PA) and muscle quality in older adults. Muscle mass, leg lean mass, lower limb extensor peak power (LLEP) and muscle quality (MQ) were measured. SB was measured using a combination of actigraphy and self-report. Habitual PA was assessed using self-report. Muscle quality was assessed using a hand-held dynamometer.

Results: Our results show an association between increased SB and decreased muscle quality. There is a direct relationship between SB and adiposity in older adults. Our results suggest that the pattern of accumulation of SB also seems to be important with less fragmented sedentary time associated with higher total body and lower limb adiposity for both men and women, indicating that individuals who break up their sedentary time have lower body fat compared with those who engage in more prolonged periods of sedentary time.

Discussion

Our results show a positive association between sedentary time and lower limb adiposity in older men. Most studies link obesity with a reduced amount of moderate or vigorous PA rather than actual SB [19]. Our results suggest that there is a direct relationship between SB and adiposity in older men. The pattern of accumulation of SB also seems to be important with less fragmented sedentary time associated with higher total body and lower limb adiposity for both men and women, indicating that individuals who break up their sedentary time have lower body fat compared with those who engage in more prolonged periods of sedentary time.

Considering these results we expected less sedentary individuals and those breaking up SB more often to have higher LLEP and MQ. Surprisingly, in men both increased sedentary time and decreased fragmentation of SB were associated with increased LLEP and MQ despite an increase in lower limb fat mass. These results are counter-intuitive but there are three possible explanations. In this high functioning group, who spend on average over an hour a day walking, carrying more body fat associated with longer sedentary time may provide a training stimulus for muscle and hence help to maintain leg power.

The second explanation is that the adoption of different PA strategies to conserve energy [20] may lead to different patterns of interruption of SB. Older adults might spontaneously compensate for an increase in energy expenditure by adopting a less fragmented SB with longer sedentary bouts. It is also possible that this is mediated by the participant’s fatigability or fitness. The greatest variance in muscle quality is explained by a combination of vigorous walking and SB fragmentation for men, hinting that muscle quality is higher if they undertake more frequent, shorter bouts of vigorous walking interspersed with longer, continuous periods of sitting. Finally it is possible that the results reflect adiposity developing in previously strong men who have recently become sedentary.

Our results show an association between a more fragmented SB and lower total body fat. Therefore, it is tempting to advocate a ‘do little, but often’ exercise prescription strategy to break down SB into shorter bouts. However, simply breaking down sedentary time does not necessarily lead to improved muscle quality which is associated with mobility [21]. This appears to depend on the intensity of the activity interruptions. Vigorous habitual PA appears to be associated with higher muscle quality but may result in spontaneous compensatory behaviour in which an older adult adopts a less fragmented SB which in turn is associated with increased adiposity. The concurrent presence of adiposity and low muscular strength is associated with sarcopenic obesity [22], so vigorous PA might have a more preventative role in males with high percentage body fat. These factors should be considered when devising exercise or PA interventions to prevent sarcopenia and obesity in older adults.

These results should however be interpreted with caution. The activity profile of the sample is comparable with that of other studies in older adults using objective measures [23]. However, the participants of our sample were healthy and high functioning therefore the range of values of body composition, muscle power and muscle quality is relatively narrow. This might explain why our results are different for women as mean and range of leg power in the women is half that of men in our sample. This lack of spread in value of leg power might explain why the effect of SB appears to follow the same trend (see Figure A1 in the Supplementary data available in Age and Ageing online) but the correlation is weaker than in the women. Other characteristics such as medication, functional capacity and amount of ambulatory activity were comparable between genders.

The intensity levels for walking are derived from models which are not specific to older adults our threshold therefore likely to be too conservative.

Table 2. Standardised coefficient $\beta$ and significance level of parameters for generalised linear model predicting muscle quality

<table>
<thead>
<tr>
<th>Model parameter</th>
<th>B</th>
<th>$\beta$ parameters</th>
<th>$p_{\text{model}}$</th>
<th>Adjusted $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>-0.465</td>
<td>0.176</td>
<td>0.118</td>
<td>0.176</td>
</tr>
<tr>
<td>$F^+$</td>
<td>-0.647</td>
<td>0.168</td>
<td>0.054</td>
<td>0.341</td>
</tr>
<tr>
<td>Total walking</td>
<td>0.287</td>
<td>0.518</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>-0.607</td>
<td>0.119</td>
<td>0.124</td>
<td>0.261</td>
</tr>
<tr>
<td>Low intensity walking</td>
<td>0.351</td>
<td>0.339</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>-0.455</td>
<td>0.279</td>
<td>0.080</td>
<td>0.427</td>
</tr>
<tr>
<td>Moderate intensity walking</td>
<td>-0.02</td>
<td>0.959</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>-0.436</td>
<td>0.123</td>
<td>0.443</td>
<td>0.053</td>
</tr>
<tr>
<td>Vigorous intensity walking</td>
<td>-0.593</td>
<td>0.049</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>-0.620</td>
<td>0.18</td>
<td>0.018</td>
<td>0.333</td>
</tr>
<tr>
<td>$F^+$</td>
<td>-0.985</td>
<td>0.035</td>
<td>0.040</td>
<td>0.340</td>
</tr>
<tr>
<td>Total walking</td>
<td>0.437</td>
<td>0.310</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>-0.583</td>
<td>0.151</td>
<td>0.069</td>
<td>0.273</td>
</tr>
<tr>
<td>Low intensity walking</td>
<td>-0.047</td>
<td>0.903</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>-0.910</td>
<td>0.070</td>
<td>0.020</td>
<td>0.420</td>
</tr>
<tr>
<td>Moderate intensity walking</td>
<td>0.457</td>
<td>0.123</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>-0.733</td>
<td>0.002</td>
<td>0.03</td>
<td>0.594</td>
</tr>
<tr>
<td>Vigorous intensity walking</td>
<td>0.534</td>
<td>0.013</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The grey area highlights the model predicting the largest amount of variance in muscle quality.

$\rho = -0.734; P = 0.003$, LLEP ($\rho = -0.683; P = 0.07$) and MQ ($\rho = -0.620; P = 0.018$).
The pattern of accumulation varies between older adults. Older adults accumulate sedentary time predominantly in long bouts.

The pattern of accumulation varies between older adults and is associated with adiposity and muscle quality.

The fragmentation of sedentary time with different activity intensity is associated with different phenotype.

Key points

- Older adults accumulate sedentary time predominantly in long bouts.
- The pattern of accumulation varies between older adults and is associated with adiposity and muscle quality.
- The fragmentation of sedentary time with different activity intensity is associated with different phenotype.

Supplementary data

Supplementary data mentioned in the text is available to subscribers in Age and Ageing online.

References