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# BMJ Open What is the effect of prolonged sitting and physical activity on thoracic spinal mobility? An observational study of young adults in a UK university setting

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## ABSTRACT

**Objective** Sedentary behaviour has long been associated with neck and low back pain, although relatively little is known about the thoracic spine. Contributing around 33% of functional neck movement, understanding the effect of sedentary behaviour and physical activity on thoracic spinal mobility may guide clinical practice and inform research of novel interventions.

**Design** An assessor-blinded prospective observational study designed and reported in accordance with Strengthening the Reporting of Observational Studies in Epidemiology.

**Setting** UK university (June–September 2016).

**Participants** A convenience sample (18–30 years) was recruited and based on self-report behaviours, the participants were assigned to one of three groups: group 1, sitters—sitting >7 hours/day+physical activity<150 min/week; group 2, physically active—moderate exercise >150 min/week+sitting <4 hours/day and group 3, low activity—sitting 2–7 hours/day+physical activity <150 min/week.

**Outcome measures** Thoracic mobility was assessed in the heel-sit position using Acumar digital goniometer; a validated measure. Descriptive and inferential analyses included analysis of variance and analysis of covariance for between group differences and Spearman's rank correlation for post hoc analysis of associations.

**Results** The sample (n=92) comprised: sitters n=30, physically active n=32 and low activity n=30. Groups were comparable with respect to age and body mass index. Thoracic spine mobility (mean (SD)) was: group 1 sitters 64.75 (1.20), group 2 physically active 74.96 (1.18) and group 3 low activity 68.44 (1.22). Significant differences were detected between (1) sitters and low activity, (2) sitters and physically active (p<0.001). There was an overall effect size of 0.31. Correlations between thoracic rotation and exercise duration (r=0.67, p<0.001), sitting duration (r=-0.29, p<0.001) and days exercised (r=0.45, p<0.001) were observed.

**Conclusions** Findings evidence reduced thoracic mobility in individuals who spend >7 hours/day sitting and <150 min/week of physical activity. Further research is required to explore possible causal relationships between activity behaviours and spinal musculoskeletal health.

## Strengths and limitations of this study

- The study employed rigorous methods and validated approaches to investigate thoracic spine functional mobility.
- The inclusion of accelerometry would have been useful to verify self-report behaviours.
- While the study sample size was based on a priori power calculation of the primary outcome, a validated measure of thoracic mobility, individual group sample size was insufficient to support further post hoc analysis.

## INTRODUCTION

### Background/rationale

Sedentary lifestyles are an undesirable hallmark of modern society, affecting a significant proportion of the population.<sup>1</sup> Prolonged sitting (a form of sedentary behaviour) has progressively become the norm with computerisation in the work place, transportation modernisation and advances in domestic technology.<sup>2</sup> These developments are not only detrimental for physiological health and well-being with rising levels of obesity, diabetes and cardiovascular disease,<sup>3</sup> but also musculoskeletal health and well-being with recent research finding an association between prolonged sitting (>8 hours a day) and increased neck-shoulder<sup>4–7</sup> and low back pain.<sup>8</sup> It is therefore reasonable to suppose that sedentary behaviours may induce musculoskeletal changes within the relatively stiff thoracic spine; contributing towards the dysfunction in the adjacent spinal regions. The term 'regional interdependence' describes a relationship whereby seemingly unrelated impairments in one anatomical region are associated with the development or persistence of pain in another.<sup>9</sup> Contributing to 33% and 21% of the movement occurring during neck flexion and rotation respectively,<sup>10</sup> it is not surprising that the thoracic spine may contribute to the

development of pain in surrounding the neck. Empirical evidence supports this theory, where thoracic movement dysfunction has been linked to pathologies in the neck<sup>11</sup> shoulder<sup>12</sup> and elbow.<sup>13</sup> Furthermore, there is a considerable body of compelling evidence to support the use of physiotherapy treatment techniques targeting the thoracic spine in clinical presentations of neck and shoulder pain.<sup>14–16</sup> Notwithstanding the paucity of literature exploring the influence of sedentary behaviours on the thoracic spine, one large cross-sectional study (n=1886) did report a relatively high prevalence of thoracic spine pain, alongside neck and back pain in sedentary workers (36%–41%), most notably in individuals with postural constraints, such as drivers and individuals unable to change tasks regularly.<sup>17</sup> However, the relationship between sedentary behaviour and thoracic mobility, a proxy for spinal musculoskeletal health, contributing 80% of axial spinal trunk rotation<sup>18</sup> has not yet been established.

Arguably, those who are physically active may present with greater mobility of their thoracic region where exercise promotes joint and soft tissue mobility, countering the deleterious adaptive shortening of muscles and joint stiffness through static postures.<sup>19</sup> However, it remains unclear what physical activity comprised in terms of 'length of activity', 'type of activity' and 'how often' the activity is performed. Physical activity has been previously defined as 'more than 150 min of moderate to intense physical activity per week'.<sup>20</sup> However, a focus on physical exertion seems inadequate when considering musculoskeletal health,<sup>21</sup> and arguably biomechanical factors such as mobility and types of activity should also be considered, where some physical activity have been subclassified as linear (straight line, eg, running) or dynamic (rotational, eg, tennis) in nature.

With sedentary lifestyles becoming increasingly the norm and evidence that sitting for just 1 hour leads to increased spinal stiffness,<sup>22</sup> it is now important to further investigate the relationship between sedentary behaviours, physical activity and thoracic spine mobility. Therefore, the aim of this study was to investigate the influence of prolonged sitting and physical activity on thoracic spine mobility.

### Objectives

1. Investigate the influence of sedentary behaviour on thoracic spine mobility.
2. Investigate the influence of physical activity on thoracic spine mobility.
3. To evaluate whether a relationship exists between duration of sitting and physical activity and thoracic mobility.

## METHODS

### Design and setting

A single assessor-blinded prospective observational study was conducted between April and June 2016 within a University setting; designed and reported in line with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.<sup>23</sup>

### Recruitment

Participants were recruited via email from the staff and student body of a large UK university using posters and email advertisement. Interested and eligible participants were provided with a participant information sheet, had their questions answered and were asked to provide written informed consent. Screening against eligibility criteria was performed at the point of recruitment by a research assistant (KT).

The study was conducted according to the Declaration of Helsinki with participants able to withdraw at any point.

### Participants

Participants comprised a convenience sample of healthy asymptomatic volunteers from within a UK university population. Eligibility criteria included young adults aged 18–30 years who fulfilled one of the following criteria based on Dunstan *et al.*,<sup>24</sup> for sitting duration and the National Institute for Health and Care Excellence Guidelines<sup>25</sup> for duration of moderate-intensity physical activity.<sup>26</sup> The sample size was based on a minimum of 30 per group to be able to detect a minimum clinically important difference (10°) in thoracic spinal rotation movement between the groups, based on power 0.8 and at 5% significance level.<sup>27</sup>

1. Individuals who participate in >150 min of physical activity per week and sit <4 hours per day (physically active).
2. Individuals who participate in <150 min of physical activity per week and sit >7 hours per day (sitters).
3. Individuals who spend between 4 and 7 hours of sitting daily and <150 min of physical activity per week (low activity).

Exclusion criteria included a current or previous neuromusculoskeletal spine condition, rheumatoid arthritis, current or chronic respiratory condition, pregnancy, current hip or knee pathology, unable to adopt heel sit position, not fulfilling one of the criteria listed above.

### Variables: demographic data and outcome assessment

#### Procedure

Piloting to determine the feasibility of the protocol was performed prior to the main study. For the main study, one researcher (KT) recruited, screened and took all baseline measures to characterise the sample (age, gender, body mass index (BMI), exercise type/duration, sitting duration). The primary measure of interest, thoracic spine mobility, was recorded by a blinded assessor (GB) with the participant in a heel-sit position.<sup>28 29</sup> Following familiarisation and three practice attempts from a position of full right to left rotation to ensure stability of measures,<sup>27</sup> the end range position of the fourth rotation was measured three times using an Acumar digital inclinometer placed over the C7–T1 interspinous space.<sup>27 29</sup> The mean of the three measures for full right and left rotations were recorded and retained for data analysis.<sup>27</sup>

### Outcome measure

The Acumar digital inclinometer (Acumar, Model ACU 360, Lafayette Instrument Company, Indiana, USA) was used to measure thoracic rotation. The heel-sit position was chosen to minimise concurrent movement occurring in the relatively mobile lumbar spine, a limitation of sitting where rotation comprises motion from both regions.<sup>28</sup> Reliability (ICC<sub>2,1</sub> (95% CI), 0.88 (0.78, 0.93)), and strong criterion (r=0.88) and concurrent validity (r=0.98) against a combined imaging and motion analysis approach have previously been established.<sup>28 29</sup>

### Bias

A number of measures were put in place to minimise the influence of bias, including use of a validated measurement approach,<sup>29</sup> standardisation of procedures through training of assessor, assessor blinding, controlling for environmental variables, avoidance of physical activity prior to testing, partial blinding of participants in that they were not made aware of a priori planned comparison between groups and piloting of all procedures in advance of the main study.

### STATISTICAL METHODS

Data were transferred to SPSS V.22 (IBM) and checked to ensure their integrity by two researchers. Descriptive statistical analyses included a summary of participant characteristics (age, gender, BMI, types of exercise, duration of exercise and sitting) using means, SD. Inferential analysis initially included one-way analysis of variance (ANOVA) to explore between-group differences and post hoc comparisons to explore between-group differences. Effect size (eta squared) was calculated and interpreted using Cohen's classification.<sup>30</sup>

Further inferential analyses included an analysis of co-variance (ANCOVA) to determine main effects including Bonferroni correction (with pairwise comparisons) to evaluate between-group differences in thoracic spine mobility with gender as a covariate (as groups were imbalanced with respect to gender). Spearman's rank correlation correlational analyses were used to evaluate the relationships between thoracic mobility and self-report measures of sitting duration, days active and physical activity. For all analyses, statistical significance was set at  $p < 0.05$ .

### PATIENT INVOLVEMENT

The study was conceived from our working with patients with spinal complaints over many years and their views were used to inform the design and methods used. Study findings have been disseminated to patients and participants via conference presentations including the Centre of Precision Rehabilitation for Spinal Pain, Patient and Public Involvement Group.

### RESULTS

#### Participants, descriptive data and outcome data

A total of 92 participants were recruited. Baseline characteristics, self-reported behaviours for physical activity (exercise duration and types of exercise) and sitting duration are presented in [table 1](#). Groups were comparable with respect to age and BMI ( $p > 0.05$ ), but not for gender with more women were recruited to the low activity and sitter group.

#### MAIN RESULTS

Thoracic spine mobility (mean, SD and 95% CI) for the sitters, physically active and low activity groups were  $64.74 \pm 6.33^\circ$  ( $62.37^\circ$  to  $67.14^\circ$ ),  $75.12 \pm 8.26^\circ$  ( $72.61^\circ$  to  $77.31^\circ$ ),  $68.28 \pm 4.36^\circ$  ( $66.02^\circ$  to  $70.86^\circ$ ), respectively ([figure 1](#)).

Results from the ANOVA showed a statistically significant difference in thoracic mobility between groups ( $F(2,56) = 20.19$ ,  $p < 0.001$ ), with a large effect size of 0.31. Post hoc comparisons of group mean scores indicated significant differences between the low activity and physically active groups ( $6.84^\circ$ ,  $p < 0.001$ ), the physically active group and sitters ( $10.38^\circ$ ,  $p < 0.001$ ), although not between the low activity and sitters ( $3.54^\circ$ ).

A one-way ANCOVA was conducted having checked data met the assumptions to compare thoracic mobility between groups, while controlling for gender. There was a significant difference between groups ( $F(2,88) = 18.66$ ,  $p < 0.001$ ) with the post hoc analyses confirming differences between the low activity and physically active groups ( $p < 0.001$ ), the physically active group and sitters ( $p < 0.001$ ), although not between the low activity and sitters.

#### Other analyses: correlational analysis

Across the whole sample, a moderate positive correlation was found between thoracic mobility and exercise duration ( $r = 0.62$ ,  $p < 0.001$ ), a low negative correlation between sitting duration ( $r = -0.25$ ,  $p < 0.05$ ) and low positive correlation between number of days exercised ( $r = 0.15$ ,  $p < 0.001$ ).

### DISCUSSION

#### Key results

This is the first rigorous observational study to investigate sedentary behaviour, physical activity and thoracic spine mobility in young adults. While no causal relationship can be inferred from this study, findings including a large effect size, provide preliminary evidence to posit a beneficial effect of physical activity and the deleterious effects of sitting on thoracic mobility, a proxy for spinal musculoskeletal health.

#### Interpretation

The low-activity group contained the highest percentage of women, with more than half the group involved in

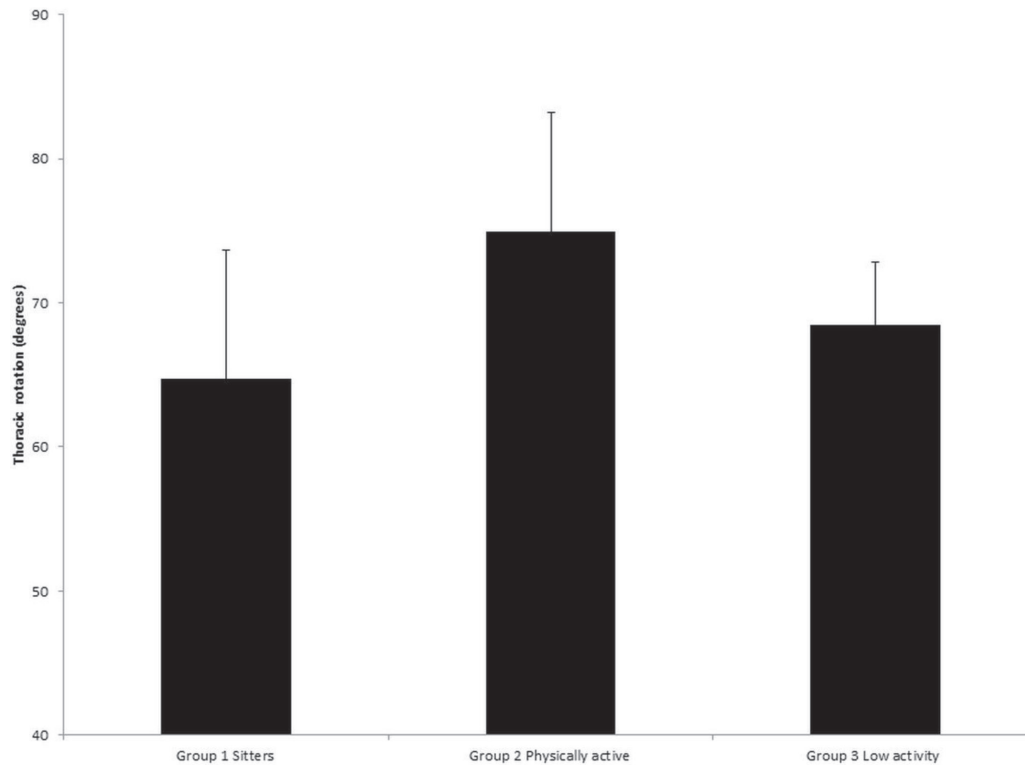
**Table 1** Participant characteristics

	Sitters, n=30	Physically active, n=32	Low activity, n=30
Age in years, mean (SD)	22.73 (2.92)	22.03 (2.65)	20.93 (2.49)
Gender (women %)	63.3*	47.0*	76.7*
BMI, mean (SD)	22.90 (2.47)	23.12 (2.92)	22.60 (2.36)
Thoracic rotation degrees, mean (SD)	64.74 (8.93)	74.96 (8.26)	68.44 (4.36)
95% CI	62.37 to 67.14	72.61 to 77.31	66.02 to 70.86
Exercise duration (minutes)			
0–30	7	–	3
30–60	4	–	6
60–90	15	–	5
90–150	4	–	16
150–180	–	4	–
180–210	–	12	–
210–240	–	5	–
240+	–	11	–
Types of exercise (frequency)			
Gym cardio	6	10	1
Gym weights	5	3	9
Running	10	6	–
Cycling	3	1	3
Dance/gymnastics	–	3	1
Football	–	4	2
Netball/basketball	–	1	1
Tennis	–	3	2
Rowing	–	1	–
Martial arts	1	–	–
Other	3	–	11
None	2	–	–
Sitting duration (hours)			
0–2	–	1	–
2–4	–	5	6
4–6	–	11	17
6–7	–	15	7
7–8	9	–	–
8–9	9	–	–
9–10	6	–	–
10+	6	–	–

\*Statistically different  $p < 0.001$ .  
BMI, body mass index.

90–150 min of physical activity and 4–6 hours sitting duration a week. Failing to meet the national guidelines for exercise<sup>31</sup> does appear to impact thoracic mobility, compared with those who are fulfilling the recommendations of >150 min of moderate physical activity per week<sup>25</sup> and sit for less than 4 hours per day.<sup>24</sup> In contrast, the findings from the physically active group endorse the Public Health England<sup>31</sup> recommendation that

exercise is beneficial for musculoskeletal health, with those involved in moderate physical activity having significantly greater thoracic mobility than those who are more sedentary. There is persuasive evidence from this study of a relationship between prolonged sitting and thoracic mobility, with >10° less mobility for the sitters compared with those who were physically active. Moreover, with sitters having approximately 4° less mobility than those



**Figure 1** Thoracic rotational mobility across groups: sitters, physically active and low activity.

in the low-activity group, our findings also support the need for further investigation of not only increased levels of physical activity, but also reduced sitting duration for optimal spinal musculoskeletal health. Although the majority of individuals in the low-activity group sit between 4 and 7 hours a day (comparable with the findings of the physical-activity group), it appears that some physical activity, although less than the recommended guidelines is beneficial to offset the ‘detrimental’ effects of sitting; with those in the low-activity group having  $>6^\circ$  less thoracic mobility than those in the physically active group.

These findings lend support for those young adults who comply with national guidelines on physical activity<sup>25</sup> having better musculoskeletal health. Findings also support the need to further investigate types of physical activity, where consideration is made specifically to biomechanical as well as physiological parameters of physical activity such as exercise intensity. With evidence of associations between thoracic mobility and exercise duration (positive), number of days exercised (positive) and sitting duration (negative), further research is now required to investigate the potentially causal relationship of reduced thoracic mobility leading to musculoskeletal complaints such as neck, thoracic and low back pain.

### Strengths and limitations

Reported in line with STROBE and employing rigorous methods, including assessor blinding, we have established differences in thoracic mobility in a large population of young adults. While self-reported measures of physical activity and sitting duration potentially lead to

underestimation or overestimation of sitting and physical activity behaviours, they are able to capture information relating to activities which are not compatible or insensitive to accelerometry such as water-based activity or cycling and stair climbing, respectively.<sup>32</sup>

Although not examined here, patterns of sitting are a potentially important consideration in future studies, where breaks have been shown to be beneficial on proinflammatory markers; linked to development of neck–shoulder pain.<sup>7</sup> Moreover, future studies could also usefully evaluate other sitting parameters where constrained or poor postures, ergonomic parameters, for example, keyboard position, may place greater loads on musculoskeletal tissues.<sup>17 33–35</sup>

### Generalisability

To enable generalisability to different populations, further studies are required with different age groups and individuals from a range of sociodemographic backgrounds. However, it is likely that this population comprising young adults is an at ‘risk’ group for developing future musculoskeletal complaints, with many likely to work in occupations where a substantial periods of time will be sitting.<sup>7</sup> Moreover, this population represents a group where there is potential to influence thoracic mobility, with spinal degenerative changes often developing at and beyond the third decade<sup>36</sup> and therefore likely less responsive to physical therapy interventions targeting stiff joints and muscles.

### CONCLUSION

This study provides evidence of reduced thoracic mobility in individuals who spend  $>7$  hours a day sitting

and <150 min of physical activity a week. With observed associations between thoracic mobility and exercise and sitting duration, further research is now required to explore the possible causal relationship between physical activity behaviours on spinal musculoskeletal health and subsequently their relationship to spinal complaints.

**Contributors** NRH was the chief investigator leading the study design, analyses and dissemination. KT and GB conducted data collection and preliminary analyses. All authors (NRH, GB, KT, DF and ABR) contributed to analysis and interpretation of results, conclusions and dissemination. NRH drafted the initial manuscript. All authors have read, contributed to and agreed on the final manuscript.

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**Data sharing statement** Raw data are held by the lead author at the University of Birmingham in accordance with guidelines. Data are available by contacting the lead author at n.heneghan@bham.ac.uk.

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