Prolonged sitting and physical inactivity are associated with limited hip extension: a cross-sectional study

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ABSTRACT

Background: It is possible that physical inactivity and prolonged sitting could lead to changes in muscle properties or bony limitations which may reduce passive hip extension.

Objectives: This study explored the association between passive hip extension and sitting/physical activity patterns.

Design: Cross sectional study

Method: The modified Thomas Test is a clinical test used to characterize hip flexion contracture. This test was used to measure passive hip extension across 144 individuals. In addition, sitting behaviours and physical activity patterns were quantified using the Global Physical Activity Questionnaire. Cut off points were defined for low/high physical activity (150 min per week), prolonged sitting (>7 hours per day) and minimal sitting (<4 hours per day). ANOVA testing was then used to compare passive hip extension between three groups, defined using the specified thresholds: low activity & prolonged sitting, high activity & minimal sitting and high activity & prolonged sitting.

Results: A total of 98 participants were allocated to one of the three groups which were shown to differ significantly in passive hip extension ($P<0.001$). Importantly, there was 6.1° more passive hip extension in the high activity & minimal sitting group when compared to the low activity & prolonged sitting group

Conclusion: This study is the first to demonstrate an association between passive hip extension and prolonged sitting/physical inactivity. It is possible that these findings indicate a physiological adaptation in passive muscle stiffness. Further research is required to understand whether such adaptation may play a role in the aetiology of musculoskeletal pain linked to prolonged sitting.

Keywords

Hip flexor, hip extension, flexibility, sitting, activity levels, Thomas test

INTRODUCTION

Sitting is the most common sedentary behavior of adults and is negatively associated with health outcomes (Hamilton et al. , 2008). Sitting increases the risk of cardiovascular disease, diabetes and premature death (Dunstan et al. , 2012). Prolonged sitting has also been shown to be related to musculoskeletal health. For example, research has demonstrated a positive association between total time spent sitting and the intensity of low back pain in blue collar workers (Gupta et al. , 2015). Studies investigating other types of musculoskeletal pain illustrate similar patterns, such as a link between the prevalence of neck-shoulder pain daily sitting time (Hallman et al. , 2015) and an association between upper quadrant musculoskeletal pain and sitting duration (Brink and Louw, 2013). These studies do not provide definitive insight into cause and effect as people with increased musculoskeletal pain may choose to sit more. However, they do motivate further research which should investigate physiological mechanisms which might underlie causal relationships between prolonged sitting and musculoskeletal pain.

Several mechanisms may underlie the observed association between prolonged sitting and musculoskeletal pain. These include muscular fatigue from continuous activation of postural support muscles (Corlett, 2006) or poor posture in sitting positions, leading to increased stress on anatomical structures (Lau et al. , 2010). Another potential mechanism is that prolonged sitting may lead to adaptive changes in passive tissue stiffness or osseous restriction which may, in turn, lead to postural malalignment and/or movement dysfunction. In sitting, the hip is flexed to approximately 90°, placing the hip flexor muscles in a slack position. It is therefore feasible that prolonged sitting could lead to an increase in passive muscle stiffness, or in osseous changes, which create a hip extension deficit, limiting passive hip extension. Such a change may increase anterior pelvic tilt (Preece et al. , 2020), changing the alignment of the lumbar spine (Glard et al. , 2005) and increasing the loads on the spine. However, at present it is not clear whether prolonged sitting is associated with differences in passive hip extension.

Changes in passive stiffness and/or muscle length can occur through several mechanisms. These include a decrease in the number of in series sarcomeres (Baker and Matsumoto, 1988) or a change in the stiffness of connective tissue (Wisdom et al. , 2015). Interestingly, it has been shown that women who regularly wear high heeled shoes demonstrate shorter muscle fascicle lengths of the gastrocnemius muscle and reduced ankle range of motion (Csapo et al. , 2010). This finding illustrates that chronic understretch of muscles can lead to increased passive stiffness. However, while chronic understretch is associated with a reduction in muscle length (Wisdom, Delp, 2015), regular participation in exercise which involves a stretch-shorten cycle, such as walking, could offset the effect of prolonged sitting. In line with this idea, it is possible that prolonged sitting, combined with low physical activity levels, could be associated with an increase in the passive stiffness of the hip flexor muscles.

The modified Thomas Test (TT) is a commonly used clinical test which can be used to assess passive hip extension (Kim and Ha, 2015, Vigotsky et al. , 2016). With this test, the patient lies supine with the non-tested knee held against the chest and the tested limb hanging freely off the end of the examination table. If the tested limb is inclined above the horizontal, this indicates shorter/stiffer hip flexor muscles (iliacus, psoas, rectus femoris, anterior portion of gluteus medius, tensor fascia latae, adductor longus and pectineus) or osseous/capsular restriction at the hip. In contrast, if the limb is inclined below the horizontal, this indicates longer/more compliant hip flexor muscles and no bony restriction. Interestingly, a large degree of inter-individual variability in the TT has been observed in healthy people, with one study reporting a range more than 22° in thigh inclination across a cohort of 24 young men (Moreside and McGill, 2012). Given the potential for physiological adaptation, it is possible that some of this inter-individual variability in passive stiffness could be the result of daily sitting patterns and physical activity levels.

Although the potential exists for prolonged sitting/physical activity to impact on passive hip flexibility, there has been minimal research aimed at understanding potential associations. To date, there has been one study investigating the association between sitting/physical activity and thoracic spine mobility (Heneghan et al. , 2018). However, this study did not include any measure of passive hip extension. Therefore, the aim of this current study was to investigate the association between passive hip extension (characterized by the TT) and prolonged sitting/physical activity. We hypothesised that prolonged sitting would be associated with reduced passive hip extension and that higher levels of physical activity would be associated with increased passive hip extension.

MATERIALS AND METHODS

Participants

A cross sectional study design was selected to address the research objective. Participants were recruited from two locations, a university and a large commercial organisation, in order to ensure a large dispersion in sitting behaviour and physical activity status. All participants gave written consent to participate and ethical approval was obtained from the university ethics committee (Reference: HST1819-358). Participants were invited to participate if they were aged between 18-65 years and had a BMI below 30. Exclusion criteria included pregnancy, a pre-existing lower quadrant musculoskeletal condition or a medical co-morbidity that hindered the ability to lie supine.

A sample size estimate was performed with the g-power software based on an estimated effect size of 0.75 SD, a critical α=0.05 and a power of 0.8. A previous study reporting normative data on TT hip extension in a healthy population suggests a SD of 6° for a homogeneous group who would be considered to lie within a central range (Moreside and McGill, 2012). We assumed a similar SD in each of our groups. With 30 in each group, this study was powered to detect a difference of 4.5° between groups.

Measurements

Following anthropometric measurements, each participant independently completed the Global Physical Activity Questionnaire (GPAQ) (Chu et al. , 2015). For this questionnaire, participants were asked to record the intensity, frequency and duration of each of the three domains in which physical activity is performed; occupational physical activity, transport-related physical activity, and physical activity during leisure time. This was completed over a typical 7-day week. Sedentary behaviour was recorded as time spent in sitting activities throughout the day, again over a typical 7-day week. To ensure an accurate measure of time spent sitting, the sedentary behaviour section of the GPAQ was modified to break the day into three periods (morning, working day, evening) which together were summed to provide a measure of total daily sitting time. To minimise bias, the researcher who carried out the physical testing (see below) was blinded to the results of the GPAQ questionnaire and had no knowledge of participant's daily sitting patterns or physical activity levels.

The TT, described in the introduction, was used to measure passive hip extension. The TT has accepted face-validity for use as a measurement tool in research (Gabbe et al. , 2004). The TT was used in conjunction with an inclinometer and a pressure biofeedback cuff to stabilize the lumbo-pelvic area in order to achieve consistency during hip measurement (Kim and Ha, 2015). For the TT, the participant was instructed to lie in a supine position with the lower gluteal folds maintained over the edge of the examination table. In this position, the pressure biofeedback cuff was inflated to 100 mmHg. The participant was then instructed to hold their knees to their chest and then to slowly lower their tested leg over the edge of the examination table, keeping the knee relaxed. At the same time, the assessor ensured that the pressure biofeedback indicator did not drop below 60 mmHg. To measure the degree of hip extension, a digital goniometer was aligned between the greater trochanter and the lateral epicondyle of the knee (Figure 1). An attached spirit level was used to ensure the reference arm was horizontal.

FIGURE 1

The TT measurement was repeated three times on both sides with a 60 second rest between each test. Following the final TT measurement, the examiner applied a small stretch to the hip flexor muscles in the testing position, described above, by applying pressure to the knee of the tested limb. Pressure was applied until the participant reported a stretching sensation in the anterior hip and there was an observable increase in hip extension without a change in the pressure biofeedback indicator. This final procedure was performed separately on each side to reduce the likelihood that the limitation in passive hip extension, measured with the TT, was a result of osseous limitation. All measurements were performed by the same author (AB) and a repeatability study was performed prior to the main study to determine the consistency of the TT. For this repeatability study, passive hip extension measurements from five individuals were taken on two separate testing sessions, four days apart. These repeated data showed an intraclass correlation coefficient of 0.9 and a standard error in the mean of 0.5°.

Statistical analysis

Following data collection, separate groups were defined using two cut off points for sitting patterns: minimal (≤4 hours per day) & prolonged (≥7 hours per day) and two cut off points for physical activity patterns: low (<150 mins per week) & high (≥150 mins per week). These cut off points were chosen to be consistent with a previous observational study, investigating the association between sedentary behaviour and thoracic spine mobility (Heneghan, Baker, 2018) and other published guidelines on minimum thresholds for physical activity (Steene-Johannessen et al. , 2016). Using the sitting and physical activity thresholds, three separate groups were defined:

Group 1: Low activity & prolonged sitting

Group 2: High activity & minimal sitting

Group 3: High activity & prolonged sitting

One-way analysis of covariance (ANCOVA) was used to understand whether hip flexor length differed between the three groups, with age included as a covariate. Where ANCOVA testing showed a significant effect, Bonferroni post hoc testing was used to explore pairwise group differences. Pearson's correlation analysis was then used to evaluate the relationship between sitting duration and TT hip extension and the relationship between physical activity duration and TT hip extension. Statistical significance was defined using a critical α=0.05. Data was analysed using SPSS, version 22.0, and Microsoft Excel 2011 software programs.

RESULTS

A total of 144 participants from two locations were recruited and tested. From this total cohort, 98 (49 male) participants satisfied the criteria for one of the three groups and were included in the final statistical analysis (Table 1). The mean (SD) age of the 98 participants was 36 (13) years and mean (SD) BMI was 24.1 (3.1) kgm^{-2}. Despite minimal differences in demographic characteristics (Table 1), TT hip extension was significantly different between the three groups ($p<0.001$, Figure 2). Specifically, participants in group 1 (low activity & prolonged sitting) had 6.1° less TT hip extension than group 2 (high activity & minimal sitting), a difference which was found to be significant on pairwise testing ($p<0.001$). However, the other two pairwise differences failed to reach significance. Specifically, the difference between the high activity/minimal sitting and high activity/prolonged sitting groups was 3.7° ($p=0.08$) and the differences between the low activity/prolonged sitting and high activity/prolonged sitting groups was 2.4° ($p=0.28$).

FIGURE 2 & TABLE 1 HERE

Across the whole cohort, a low but statistically significant *c*orrelation was found between TT hip extension angle and exercise duration ($r=0.35$, $p<0.01$). A similar low correlation was also observed between hip extension angle and sitting duration ($r=-0.28$, $p<0.01$). Tables 2 and 3 provide a summary of the distribution of physical activity level and sitting duration respectively across the three groups. These data illustrate the range of activity and sitting patterns across the whole cohort and within each individual group.

TABLE 2 & TABLE 3 HERE

DISCUSSION

The aim of this study was to explore the association between prolonged sitting/physical activity and passive hip extension. In line with our hypothesis, the data demonstrated that people who are inactive and sit for long periods each day have lower levels of passive hip extension when compared to active people who spend less time sitting. Our motivation for this study was based on the idea that physical inactivity and prolonged sitting could lead to increased passive stiffness in the hip flexor muscles. While we took steps to minimise the potential for osseous mechanisms to influence our measure of passive hip extension, it is not possible to completely rule out the potential influence of bony restriction. Furthermore, as our study was cross sectional in nature, it does not demonstrate causality. Nevertheless, these findings indicate the potential for physiological change in the hip flexor muscles in people who are sedentary and sit for prolonged periods.

The data also indicated that, in the participants who sat for prolonged periods (group 1 and 3), there was increased passive hip extension in those who were more active (Figure 2). However, this difference failed to reach significance. Therefore, while it is possible that increasing activity levels may offset the effect of prolonged sitting to some degree, there appears to be some effect of prolonged sitting even in those who are more active.

In their recent study, Heneghan *et al.* (2018), sought to understand the association between prolonged sitting/physical activity levels and the mobility of the thoracic spine. Like the current study, they showed that prolonged sitting (>7 hours per day) and low levels of activity (<150 min per week) were associated with a lower range of active rotation of the thoracic spine. Although this finding may indicate larger intrinsic spinal stiffness in people who are less active, it may also indicate more passive stiffness in abdominal muscle structures which are required to lengthen to facilitate thoracic rotation. The findings of the current study show that decreased passive hip extension is associated with prolonged sitting. Taken alongside the results of Heneghan *et al.* (2018), the data may indicate that both hip flexor and abdominal muscles are shorter/stiffer in people who sit for prolonged periods and who are inactive.

There are several physiological mechanisms which, in the absence of bony restriction, may underlie the observation of reduced passive hip extension in the group who were inactive and sat for prolonged periods. Firstly, it is possible that prolonged sitting and physical inactivity may lead to an increase in the stiffness of connective tissue, which can occur at both the subcellular and the tissue level of the muscle (Wisdom, Delp, 2015). At the subcellular level, the protein titin connects myosin filaments to the z-disc and is believed to be the major contributor to passive muscle stiffness along the fiber direction (Gajdosik, 2001). Research suggests that titin may adapt to different loading patterns and has been shown to become less elastic with induced unloading in animal models (Goto et al. , 2003). At the tissue level, the extracellular matrix, which consists primarily of collagen, contributes significantly to the passive mechanical properties of muscle (Smith et al. , 2011). It is well-established that the mechanical properties of the extracellular matrix are dependent on loading patterns (Kjaer, 2004) and it is feasible that it may become stiffer with lower levels of physical activity.

Our observation of decreased TT hip extension may also indicate a reduction in the number of in series sarcomeres in people who lead more sedentary lifestyles. Fine wire EMG studies of the psoas and iliacus muscles have shown that these two hip flexor muscles are active during sitting (Andersson et al. , 1995) but that activation is dependent on the sitting posture adopted (Park et al. , 2013). It is therefore possible that in some individuals, these muscles undergo a shortening adaptation, with a reduction in the number of sarcomeres in series in order to reduce the length at which maximum force production occurs (Wisdom, Delp, 2015). Such adaptation may enhance postural control in sitting, enabling the hip flexors muscles to function at a shorter length, however, this may lead to altered postural control in standing, potentially increasing anterior rotation of the pelvis (Preece, Fang, 2020). Importantly, although we observed differences at a group level, bivariate correlations were relatively low, suggesting the influence of other factors. Given the dependence of hip flexor activation on sitting posture (Park, Tsao, 2013), it is possible that a reduction in the number of in series sarcomeres occurs more readily in individuals who have higher muscle activation levels in sitting. Clearly further research is required to explore this idea and understand the influence of hip flexor activation in sitting on long-term changes in passive muscle stiffness.

Several epidemiological studies have linked musculoskeletal pain with prolonged sitting (Brink and Louw, 2013, Gupta, Christiansen, 2015, Hallman, Gupta, 2015, Kim, 2019). Our data show that prolonged sitting is associated with reduced passive hip extension and it is possible that such a changes could play a role in mechanisms of chronic musculoskeletal pain. This study therefore motivates further work which should explore potential links between sedentary behaviour, adaptive muscle shortening/stiffening, osseous restriction and musculoskeletal pain. Our data do not demonstrate causality. However, it is unlikely that reduced passive hip extension is driving behavioural choices in daily sitting habits, many of which are determined by the nature of an individual's occupation. It is therefore reasonable to make tentative clinical recommendations that patients who demonstrate limited hip extension on passive testing be encouraged to increase participation in physical activity and minimise periods of prolonged sitting.

There are several limitations to this study which should be highlighted. Firstly, we used a clinical technique, the TT, to measure passive hip extension. This limits our ability to make definite conclusions about muscle stiffness/length because this test does not exclusively assess musculotendinous structure. However, we took steps to minimise the potential impact of bony restriction, building on a protocol which has shown to be been valid (Vigotsky, Lehman, 2016) and reliable (Kim and Ha, 2015). Whilst the range of passive hip extension found in this study was similar to that observed by Moreside and McGill (2012), further research is required using imaging techniques to fully understand the potential influence of bony restriction in individuals who report no pain. Secondly, we used a questionnaire to quantify physical activity patterns which can lead to recall bias, underestimation or overestimation. Nevertheless, three separate groups were defined using appropriate cut off points for sitting/physical activity patterns and individuals who did not meet these criteria were excluded. Future work could be carried out using objective quantification of temporal sitting/activity patterns and this may provide further insight into the link between sedentary behaviour and passive hip extension.

In our cohort of healthy volunteers, we observed limited passive hip extension in people who sat for prolonged periods and were inactive. It is possible that this observation reflects an increase in passive stiffness of the hip flexor muscles which may be a physiological adaptation to prolonged sitting. Our data may indicate that increasing levels of physical activity could offset, to some degree, this physiological adaptation. However, further research is required to fully understand the links between sitting behaviour, muscle adaptation, osseous restriction and physical activity. It is possible that such research may provide new insight into the aetiology of musculoskeletal pain associated with prolonged sitting.

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FIGURES AND TABLES:

Figure 1: Testing protocol for the modified Thomas Test (TT).

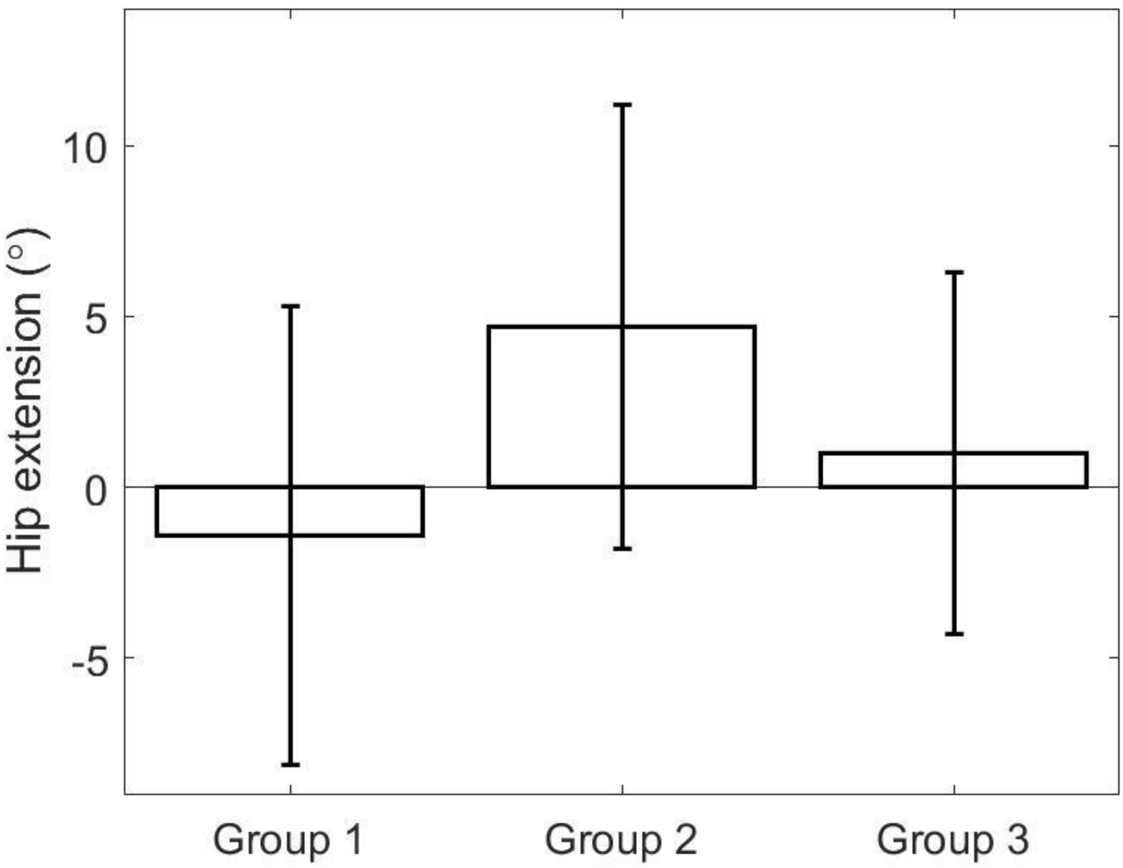

Figure 2: Mean (SD) Thomas Test (TT) hip extension for the three groups (Group 1: low activity & prolonged sitting, Group 2: high activity & minimal sitting, Group 3: high activity and prolonged sitting). The horizontal line indicates statistical significance, $p<0.001$.

	Group 1 Low activity & prolonged sitting	Group 2 High activity & minimal sitting	Group 3 High activity & prolonged sitting
Number of participants	38	30	30
Age, mean (SD)	37 (14) years	37 (12) years	35 (13) years
Gender (women%)	50	50	50
BMI, mean (SD)	23.7 (3.1) kgm^{-2}	24.1 (3.6) kgm^{-2}	24.5 (2.7) kgm^{-2}
TT hip extension angle, mean (SD)	-1.4° (6.7°)	4.7° (6.5°)	1.0° (5.3°)

TABLE 1: Demographic characteristics and passive hip extension measurements of the three groups

Physical activity (minutes per week)	Group 1 Low activity & prolonged sitting. **n=38**	Group 2 High activity & minimal sitting. **n=30**	Group 3 High activity & prolonged sitting. **n=30**
0-30	16	-	-
30-60	5	-	-
60-90	5	-	-
90-150	12	-	-
150-180		6	18
180-210		7	6
210-240		6	2
240+		11	4

TABLE 2: The distribution of physical activity for the three groups. The value in each column shows the number of participants within the corresponding range of physical activity.

Sitting duration (hours per day)	Group 1 Low activity & prolonged sitting. **(n=38)**	Group 2 High activity & minimal sitting. **(n=30)**	Group 3 High activity & prolonged sitting. **(n=30)**
0-2	-	-	-
2-4	-	27	-
4-6	-	3	-
6-7	-	-	-
7-8	9	-	12
8-9	7	-	5
9-10	9	-	6
10+	19	-	7

TABLE 3: The distribution of sitting duration for the three groups. The value in each column shows the number of participants within the corresponding range of sitting duration.