Clinical Study

Does sedentary behavior increase the risk of low back pain?
A population-based co-twin study of Spanish twins

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Abstract

BACKGROUND: The relationship between sedentary lifestyle and low back pain (LBP) remains unclear and previous research has not accounted for genetic and early environmental factors.

PURPOSE: Our aim was to investigate if sedentary behavior is associated with the lifetime prevalence of persistent LBP and the risk of developing persistent LBP, care-seeking due to LBP, and activity limiting LBP when genetics and early environmental factors are accounted for.

STUDY DESIGN: Both cross-sectional and longitudinal designs with a within-pair twin case-control were implemented.

PATIENT SAMPLE: There were 2,148 twins included in the cross-sectional analysis whereas 1,098 twins free of persistent LBP at baseline were included in the longitudinal analysis.

OUTCOME MEASURES: Sedentary behavior was the explanatory variable. Lifetime prevalence of LBP was the outcome variable in the cross-sectional analysis. The incidence of persistent LBP, care-seeking due to LBP, and activity limiting LBP were the outcome variables for the longitudinal analysis.

METHODS: This observational study was supported by a grant in 2012. No competing interests were declared.

RESULTS: In the cross-sectional analysis, sedentary behavior was slightly associated with an increased prevalence of persistent LBP in females but not in males. This association was not apparent when genetics and early environmental factors were accounted for. We acknowledge that the small sample included in the co-twin analyses have yielded wide confidence intervals, and that caution should be exercised when interpreting and an association may not be ruled out. In the longitudinal analysis, sedentary behavior did not significantly increase the risk of persistent LBP, care-seeking due to LBP, or activity limiting LBP.
Introduction

Low back pain (LBP) is one of the most prevalent health conditions worldwide and the personal and societal burden associated with LBP makes it a major public health concern [1]. Relapses in pain (60%) and work absences (33%) are common and substantially contribute to LBP being the highest contributor to disability in the world [2,3]. In Spain alone, the estimated average annual cost in lost working days for LBP between 2000 and 2004 was over €160 million [4].

Recommended treatments for LBP offer only moderate benefits, failing to significantly reduce pain and associated disability, particularly in people with chronic symptoms [5]. Therefore, the identification of risk factors for LBP and the resultant prevention strategies are crucial [6]. A significant number of risk factors has been investigated in LBP; however, most do not show a strong or consistent association with LBP [7]. For example, even though obesity is frequently reported as a risk factor for LBP, its effect is weak and disappears when factors such as genetics and early environment are considered [8].

Lifestyle behaviors can significantly affect an individual’s health. Modern living increases the tendency for people to adopt a more sedentary lifestyle including more time spent in sitting [9,10]. Parallel to the decline in people’s engagement in daily levels of physical activity, research suggests that musculoskeletal pain is more common now than it was 40 years ago [11]. This reduction in physical activity levels is not only associated with the rise in chronic diseases such as obesity and diabetes [12,13], but also potentially contributing to an increase in the prevalence and incidence of musculoskeletal pain and disability [14]. For the general population, it has been suggested that sedentary behavior is associated with a higher prevalence of LBP [15,16].

To further highlight the multidimensional nature of LBP, there is now increasing evidence that genetic factors play an important role in the development and prevalence of this condition [17,18]. Twin studies have shown that genetic factors contribute to the development of LBP [19,20], with a recent systematic review indicating that heritability of LBP could be as high as 67% [21]. The genetic influence in LBP appears to be higher for more persistent and disabling cases [22]. Moreover, it has been suggested that the genetic makeup of a person might moderate the influence of physical activity, or sedentary behavior, on LBP [23].

Although previous studies [14,24] have assessed the association between sedentary behavior and LBP, to our knowledge, no study has explored the influence of sedentary behavior on lifetime prevalence and occurrence of new cases of LBP using a twin design that controls for the genetic effects on LBP. It is likely that the relationship between sedentarism and LBP is not elucidating without the consideration of genetics and early environmental factors. Therefore, we aimed to investigate whether sedentary behavior is associated with the lifetime prevalence of LBP and with the risk of developing persistent LBP after adjusting for genetic and early environmental influences in a sample of adult twins from Spain.

Methods

Design

We conducted both a cross-sectional and a longitudinal observational study using a within-pair twin case-control design.

Study sample and data collection

The study sample comprised monozygotic (MZ) and dizygotic (DZ) twins registered in a population-based twin registry of adult multiples born between 1940 and 1966. The registry currently has over 2,200 participants. Information on the registry characteristics and recruitment procedures can be found elsewhere [25].

Twin zygosity was ascertained by DNA in 338 twin pairs. When this was not possible, a 12-item questionnaire focusing on the degree of similarity and mistaken identity was used. This questionnaire has been determined by DNA testing to correspond well with zygosity with an agreement in nearly 96% of cases [25]. All registry and data collection procedures involved in the present study obtained ethics approval.

Cross-sectional analysis

Data were collected between 2009 and 2011 (baseline) for female, male, and opposite-sex twin pairs irrespective of participants’ prevalence of LBP. Trained assessors using phone and face-to-face interviews that included demographic information and self-reported health-related questionnaires conducted data collection. Assessors were blinded to the predictors and outcomes of the study. The primary outcome investigated in the cross-sectional analysis was lifetime prevalence of persistent LBP. Lifetime prevalence of persistent LBP was assessed with the following question: “Have you ever suffered from chronic LBP?,” with persistent LBP defined and explained to participants as the presence of pain in the lower back area that lasted for 6 months or longer, including seasonal or recurrent episodes.

CONCLUSIONS: Sedentary behavior is associated with concurrent LBP. However, this association is weak; it only appears in females and decreases when accounting for genetics. Future studies using a twin design with larger samples should be conducted to further test these findings. © 2017 Elsevier Inc. All rights reserved.

Keywords: Epidemiology; Genetics; Low back pain; Physical activity; Sedentary behavior; Twin study
EVIDENCE & METHODS

Context
Whether a sedentary lifestyle (or an active one) is associated with chronic low back pain remains an open question.

Contribution
In this twin study, the authors found a weak association in more sedentary females only.

Implications
The beauty of twin studies is that they allow comparisons between groups that often have identical nature (genetics), very similar nurture (setting, upbringing), and possibly quite varied adult life and lifestyles, so the impact of these variables is less confounded and more clearly delineated. The problem, however, is the small numbers and the incomplete data often collected in these studies. Accordingly, important differences may elude detection. (So the couch-sitter should not be reassured at this point, nor the fitness-obsessed millennial discouraged.)

Longitudinal analysis
Twins were included in the longitudinal analysis if they answered the questionnaire both at baseline (from 2009 to 2011) and at follow-up (2013), and did not report persistent LBP at baseline, based on the question of lifetime prevalence of LBP.

The main outcomes investigated in the longitudinal analysis were the occurrence of new cases of LBP, care-seeking associated with persistent LBP, and activity limiting LBP. Dichotomous data on persistent LBP were gathered by asking participants the following question: “Have you ever suffered from chronic LBP?” Those participants who answered “yes” to this question at follow-up were considered as having persistent LBP. This question was followed by “Did you seek medical help because of your persistent LBP?,” with care-seeking defined as any medical help (including general practitioner or physiotherapist) sought because of LBP. Additionally, participants were asked the following question: “Was this pain bad enough to limit your usual activities or change your daily routine for more than one day?” Those participants who answered “yes” for these questions were considered as “cases” for care-seeking, and for activity limiting LBP.

Explanatory variable
Data on sedentary behavior were collected using a categorical self-reported questionnaire involving 2 separate types of physical activity questions: daily (work, domestic related) and leisure (recreational) physical activity. Participants were first asked to choose the best option that described their engagement in daily physical activity. The options included the following: (1) “sitting most of the time”; (2) “standing most of the time”; (3) “walking and transporting light weights with frequent displacements, without using intense physical effort”; and (4) “doing tasks that require a strong physical effort.” They were then asked to select the best option that described their engagement in leisure physical activity. The options included the following: (1) “I do not practice exercise. My leisure time is mostly sedentary (reading, watching TV, movies etc.)”; (2) “Some sport or physical activity occasionally (walking, gardening, soft gym, light efforts etc.)”; (3) “regular physical activity several times a month (tennis, jogging, swimming, cycling, team sports etc.)”; or (4) “physical training several times a week.” Participants were categorized as sedentary if they answered “sitting most of the time” or “standing most of the day with light physical efforts or movements” for daily physical activity; and also answered “I do not practice exercise, my leisure time is mostly sedentary (reading, watching TV, movies etc.)” for leisure physical activity. The remaining sample was categorized as nonsedentary. All questions were based on the Spanish National Health Survey questionnaire [26]. The National Statistics Institute monitors methodology for the Spanish National Survey. This questionnaire has been used since 1987. Multiple reports from the Spanish Minister have been based on those questions [18,27].

Potential confounders
We performed univariate logistic regression models to explore potential confounders that should be adjusted for in the multivariate models. Age was entered in the models as a continuous variable. Potential confounders included age, sex, body mass index (BMI), smoking, sleep quality, and symptoms of depression or anxiety. Data on smoking were entered as a dichotomous variable (current/occasional smoker or ex/never smoker) whereas data on BMI were recorded as a continuous variable. Participants’ subjective sleep quality was assessed using the Spanish version of the Pittsburgh Sleep Quality Index [30] and a dichotomous score was used for analyses, based on the total score cutoff point of 5, with a score greater than 5 indicating poor sleep quality [24]. Data on symptoms of depression or anxiety were collected using the corresponding domain of the EuroQol-5 dimension questionnaire [31]. Participants were categorized into not depressed/anxious or moderately/very depressed/anxious. We included variables in the multivariate logistic regression models if the p-values in the univariate models were <.2, except for age and sex that were included into all multivariate analyses to allow comparability between analytical models (ie, from total sample through within-pair twin case-control analyses, where same-sex twins are naturally matched for age and sex).

Data analysis
We attempted to perform the analysis investigating the association between sedentary behavior and each LBP outcome,
for both the cross-sectional and longitudinal analyses, in 3 steps: (1) total sample analysis, (2) within-pair case-control analysis for only DZ twins, and (3) within-pair case-control analysis for only MZ twins.

We first investigated the association between sedentary behavior and LBP outcomes separately in the total sample of twins using complete and incomplete twin pairs regardless of concordance or discordance for LBP. Because twin pairs were followed up for different periods, the total sample analyses were adjusted for follow-up length. Both twins within a pair were followed for the same period of time; therefore, the within-pair case-control analyses were not adjusted for follow-up length.

To adjust for genetic and early shared environmental influences on the association between sedentary behavior and persistent LBP, we performed a subsequent within-pair twin case-control analysis on all complete DZ and MZ twin pairs discordant for LBP (1 twin reported persistent LBP [case] whereas the other did not report persistent LBP [control]). For the longitudinal analysis, discordance of LBP was considered at follow-up for each LBP outcome separately. To allow for a comparison of models between all twins and the case-control analyses, the same variables that entered the multivariate models in the total sample analysis were also included in the case-control analysis, with irrelevant variables omitted (eg, sex in MZ-only analysis). We used a fixed-effect model in our analysis as a standard procedure. Conditional logistic regression was used to perform the within-pair twin case-control analysis. The analysis was performed separately for males and females, depending on the availability of subsamples. In theory, the levels of adjustment for confounders increase in each analytical phase: total sample analysis >> DZ case-control analysis >> MZ case-control analysis. In the total sample analysis, the adjusting variables are derived from the data only. In the within-pair twin case-control analysis, adjustment for genetic and early shared environmental factors is also employed, in addition to the confounders derived from the data. DZ twins share approximately 50% of their genes, whereas MZ twins share about 100% [32].

Although the use of DZ twins allows for the adjustment of early common shared environment and partially genetics when investigating risk factors for a condition, the full adjustment for both the genetic effects and early common shared environment is achievable with the use of MZ twins in the analysis. By examining the patterns of associations (and not p-values in isolation) between risk factors and a condition, progressively from DZ twin pairs to MZ twin pairs, it is possible to sequentially control for the impact of early common shared environment and genetics, thereby gaining insights into possible causal relationships between variables.

Therefore, the MZ model provides the most adjusted and precise result estimation. In theory, if the magnitude of the association between 2 variables increases (or remains significant) across the analytical phases, this is indicative of a causal relationship, as the analyses get more direct and cleaner throughout the phases. However, if the magnitude of the association decreases or disappears, this is indicative of the initial identified association being confounded by early shared environment and genetic factors (Figure). We interpreted results based on the magnitude and plausibility of the associations, as well as confidence intervals, rather than exclusively on p-values [33,34].

We set the α level for all the final regression models at <0.05. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated and data analysis was performed using Stata statistical software (version 13.0, STATA Corp., College Station, TX, USA).

Results
Cross-sectional analyses
Sample characteristics
A total of 2,537 adult twins were initially contacted to complete the initial health and lifestyle questionnaire, and 380 declined participation for various reasons, with an overall response rate of 85%. Data on lifetime prevalence of persistent LBP were available from 2,148 twins irrespective of concor-
dance or discordance for LBP, and these data were included in the total sample analyses. A total of 361 complete and discordant MZ and DZ twin pairs were incorporated in the within-pair twin case-control analyses. Female participants accounted for 55% of the sample, and mean age of all participants was 53.7 years, with no significant difference in mean age between males and females. The overall lifetime prevalence of persistent LBP was 32%. In terms of sedentary behavior, 58% of the sample reported to be physically inactive (Table 1).

Sedentary behavior and lifetime prevalence of persistent LBP

In the total sample analysis, the variables entered the multivariate model were sedentary behavior, BMI, sex, smoking, sleep quality, and symptoms of depression or anxiety. The multivariate analysis showed that sedentary behavior was weakly associated with lifetime prevalence of persistent LBP, being of borderline significance (OR: 1.2, 95% CI: 0.98–1.46, p=.06). When the total sample analyses were stratified by sex, sedentary behavior was associated with an increased prevalence of persistent LBP in females (OR: 1.5, 95% CI: 1.16–1.91, p=.001), but not in males (OR: 0.8, 95% CI: 0.54–1.12, p=.19). Similar results in terms of magnitude were found in the within-pair twin case-control analyses for DZ twins. In the within-pair twin case-control analyses for MZ twins, the magnitude of the association was equal for both sexes and not statistically significant (OR: 1.5, 95% CI: 0.79–2.97, p=.20 [all individuals], OR: 1.4, 95% CI: 0.62–3.20, p=.41 [females], OR: 1.4, 95% CI: 0.39–4.64, p=.62 [males]) (Table 2).

Longitudinal analysis

Sample characteristics

From the 1,607 participants who answered the questionnaires at baseline and follow-up, 1,098 twins did not have persistent LBP at baseline and were included in the longitudinal analysis. The reported mean age was 54 (SD=7.3) years, and 53% were male. The overall occurrence of new cases of LBP was 22%; 171 twins (16%) reported care-seeking associated with LBP and 205 twins (19%) reported activity limitation associated with LBP. In terms of sedentary behavior, 56% of the sample was categorized as sedentary (Table 3).

Sedentary behavior and persistent LBP

In the total sample analysis for persistent LBP, the variables sedentary behavior, age, sex, and symptoms of depression or anxiety entered the multivariate model. In the total sample analysis, sedentary behavior at baseline did not independently increase the risk of developing persistent LBP (OR = 1.3, 95% CI: 0.92–1.69, p=.15). We found a similar pattern in the

<table>
<thead>
<tr>
<th>Variables</th>
<th>All participants</th>
<th>Lifetime prevalence of chronic LBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>2,148, 53.6 (7.3)</td>
<td>694, 53.7 (7.3), 1,454, 53.4 (7.2)</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>971, 45.2</td>
<td>212, 30.5, 759, 52.2</td>
</tr>
<tr>
<td>MZ male</td>
<td>288, 13.4</td>
<td>59, 8.5, 229, 15.8</td>
</tr>
<tr>
<td>MZ female</td>
<td>419, 19.5</td>
<td>181, 26.0, 238, 20.1</td>
</tr>
<tr>
<td>DZ male</td>
<td>362, 16.8</td>
<td>85, 12.2, 277, 16.8</td>
</tr>
<tr>
<td>DZ female</td>
<td>407, 18.9</td>
<td>181, 26.0, 226, 15.9</td>
</tr>
<tr>
<td>DZ opposite sex</td>
<td>672, 31.2</td>
<td>188, 27.0, 484, 33.2</td>
</tr>
<tr>
<td>Depression and anxiety*</td>
<td>466, 21.8</td>
<td>219, 31.6, 247, 17.1</td>
</tr>
<tr>
<td>Sleep quality†</td>
<td>958, 44.6</td>
<td>99, 40.4, 318, 37.3</td>
</tr>
<tr>
<td>Smoking‡</td>
<td>892, 41.7</td>
<td>303, 43.8, 589, 40.7</td>
</tr>
<tr>
<td>Sedentarism§</td>
<td>1,011, 57.8</td>
<td>351, 60.5, 660, 56.5</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>2,091, 27.4</td>
<td>675, 27.7, 1,416, 27.3</td>
</tr>
</tbody>
</table>

BMI, body mass index; DZ, dizygotic; LBP, low back pain; MZ, monozygotic; n, number of participants; SD, standard deviation.

* Indicates presence of symptoms of depression and anxiety.
† Indicates poor sleep quality.
‡ Indicates current smokers.
§ Indicates presence of sedentary behavior.

<table>
<thead>
<tr>
<th>Multivariate models*</th>
<th>OR (95% CI)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sample analysis</td>
<td>All individuals (n=2,058 twins)</td>
<td>1.2 (0.98–1.46)</td>
</tr>
<tr>
<td>Female (n=1,112 twins)</td>
<td>1.5 (1.16–1.91)</td>
<td>.001</td>
</tr>
<tr>
<td>Male (n=946 twins)</td>
<td>0.8 (0.54–1.12)</td>
<td>.191</td>
</tr>
<tr>
<td>DZ case-control analysis</td>
<td>All individuals (n=456 twins)</td>
<td>1.3 (0.82–2.02)</td>
</tr>
<tr>
<td>Female (n=150 twins)</td>
<td>1.8 (0.81–3.88)</td>
<td>.146</td>
</tr>
<tr>
<td>Male (n=306 twins)</td>
<td>0.6 (0.24–2.95)</td>
<td>.806</td>
</tr>
<tr>
<td>MZ case-control analysis</td>
<td>All individuals (n=228 twins)</td>
<td>1.5 (0.79–2.97)</td>
</tr>
<tr>
<td>Female (n=72 twins)</td>
<td>1.4 (0.62–3.20)</td>
<td>.410</td>
</tr>
<tr>
<td>Male (n=156 twins)</td>
<td>1.4 (0.39–4.64)</td>
<td>.626</td>
</tr>
</tbody>
</table>

CI, confidence interval; DZ, dizygotic; MZ, monozygotic; n, number of participants; OR, odds ratio.

* Adjusted for age, sex, sedentarism, depression/anxiety levels, sleep quality, smoking, and body mass index.
within-pair case-control analysis for DZ only (Table 4). However, in the within-pair case-control analysis for MZ only, there was an increase in the risk of developing persistent LBP in sedentary twins (OR = 4.0, 95% CI: 0.85–18.84, p = .08), although not statistically significant. We could not stratify the analysis by sex because of small numbers.

### Sedentary behavior and care-seeking due to LBP

In the total sample analysis for care-seeking associated with LBP, the variables that entered the multivariate model were sedentary behavior, age, sex, depression, and sleep quality. In the total sample analyses, sedentary behavior at baseline did not increase the occurrence of new cases of care-seeking due to LBP (OR = 1.3, 95% CI: 0.93–1.78, p = .12). However, in the within-pair twin case-control analyses for MZ only, there was also an increase in the risk of care-seeking due to LBP in sedentary twins (OR = 3.5, 95% CI: 0.72–17.19, p = .12), although the estimate was not statistically significant (Table 4).

### Sedentary behavior and activity limiting LBP

In the total sample analysis for activity limiting LBP, the variables that entered the multivariate model were sedentary behavior, age, and sex. Sedentary behavior did not increase the risk of activity limiting LBP (OR = 1.4, 95% CI: 0.96–1.93, p = .07). However, in the within-pair twin case-control analyses for MZ twins only, there was a large, but not statistically significant, increase in the risk of activity limitation associated with LBP in sedentary twins (OR = 5.0, 95% CI: 0.58–42.79, p = .14) (Table 4).

### Discussion

#### Summary of findings

The aim of the present study was to determine the association between sedentary behavior and the prevalence of persistent LBP, as well as the risk of developing persistent LBP, care-seeking due to persistent LBP, and activity limiting LBP, after adjusting for genetic and early environmental influences. The findings of the cross-sectional analysis suggest that sedentary behavior is associated with a higher lifetime prevalence of persistent LBP in females, but not in males, in the
total sample analysis. This association remains similar for females and increases in males (although not statistically significant) when genetics and early shared environment are controlled for. Our longitudinal analysis allowed us to additionally investigate the influence of sedentary behavior in the risk of future LBP but did not show a reliable influence of the former in any of the LBP outcomes, although, when genetics and early shared environment were controlled for, an association could be plausible. However, this interpretation is based on the magnitude of the estimates and plausibility of findings in addition to the investigation of p-values as previous research has recommended for interpretation of observational data [33,34,35]. Therefore, because results did not reach statistical significance and produced large confidence intervals, we advocate caution when interpreting these results. Nevertheless, the present study indicates that the effect of sedentary behavior on LBP may not be comprehensively investigated in studies that do not control for possible genetic and early environmental influences on the sedentarism-LBP relationship.

Comparison of findings with previous research

Our study investigated several LBP-related outcomes, including not only the presence of persistent LBP, but also activity limiting LBP and care-seeking associated with LBP. It is also important to note that the relationship between LBP and sedentarism might vary depending on the type and dosage of physical activity. For instance, results from a systematic review have shown that recreational physical activity can be effective in preventing LBP; however, people who engage in prolonged, heavy loading type of physical activities are at higher risk of developing future LBP [36]. It is important to note that we attempted to investigate whether people with a sedentary lifestyle, rather than engaged in one particular type of physical activity, are at higher risks of developing LBP, through a combination of data on leisure and work-related physical activity.

Previous systematic reviews that included cross-sectional and longitudinal studies have not identified an association between work-related sedentary behavior [37] as well as more comprehensive definitions of sedentary behavior (including prolonged sitting both at work and during leisure time) [15] and LBP. The current study found a small and close to significant increase in risk of persistent LBP in the total sample analysis (OR=1.3, 95% CI 0.92–1.69), with similar magnitude of estimates to non-twin studies (eg, pooled OR=1.4, 95% CI 0.73–2.78) [24]. However, in the MZ twins case-control analysis, we observed an increase in risks of persistent LBP (OR=4.0, 95% CI 0.85–18.84) compared with the total sample analysis. We observed a similar pattern for the outcomes of care-seeking due to LBP (OR=3.5, 95% CI 0.72–17.19) and activity limiting LBP (OR=5.0, 95% CI 0.58–42.79). It should be noted, though, that for the latest outcomes large confidence intervals were observed (Table 4), which probably reflect the reduction in sample sizes for the case-control analyses. However, these results point to the possibility of a complex relationship between sedentarism and LBP that should be further investigated in a larger sample of twins discordant for LBP outcomes.

The results of our total sample analyses also showed a higher prevalence of persistent LBP in sedentary women compared with nonsedentary ones, with no significant differences observed in males. Previous studies found that females experience greater pain sensitivity levels [38,39] and are more likely to self-report pain compared with males [40]. Although these reasons could explain why sedentary women are more prone to LBP compared with men, these explanations need to be viewed with caution, given that our MZ twins analysis revealed similar estimates for the association between sedentarism and LBP across both sexes. It is likely that the initial differences in estimates between sexes observed in our total sample analyses are, in fact, confounded by genetic and early environmental factors. It should be noted, though, that we were only able to investigate differences between sexes in the cross-sectional analysis, which limits our inferences on possible direct causal paths between sedentary behavior and LBP across sexes.

Strengths and limitations

The present study has several strengths such as the use of a longitudinal design, comprehensive assessment of LBP, and a twin analytical approach, although some limitations should be noted. Firstly, the outcome measure of lifetime prevalence of persistent LBP is relatively simplistic, and measures of the impact of LBP on function and disability levels were not available for our cross-sectional analyses. Secondly, the LBP measures used to classify participants as free of LBP at baseline assessed persistent LBP, and therefore it is likely that participants with a recent episode of LBP (<6 months) could be included in the analysis. Furthermore, we cannot rule out the possibility of recall bias because participants were asked to report their experience of having persistent LBP (>6 months) through their lifespan. This might have influenced the results, because a previous history of LBP is a risk factor for developing a new episode in the future [41]. Additionally, data on sedentary behavior were self-reported based on the physical activity questionnaire, and it is known that participants are likely to overestimate [42,43] or underestimate their engagement in physical activity when completing self-reported measures. Furthermore, although the self-reported physical activity questionnaire used in the present study has been previously reported in several publications [5,6,26,28,29], it has not been validated before. The self-reported nature of physical activity and LBP report further limit the findings of the present study. Lastly, it was not possible to conduct all analytical phases stratified by sex in the longitudinal analysis because of the reduced sample size.

Implications of study findings

Although the literature presents widespread evidence on management strategies following an episode of LBP [44], it
offers limited evidence on prevention strategies. This can be observed in clinical guidelines such as the physiotherapy Dutch clinical guidelines [44] and the American Pain Society clinical guidelines [45]. The paucity of evidence for LBP prevention strategies may be attributed to the current lack of strong and consistent risk factors for LBP [46]. A recent study conducted by our group has shown that people seeking care for LBP and who are more physically active have less pain and disability at 12-month follow-up [47]. Another recent systematic review showed that exercise alone or in combination with education is effective for preventing LBP [48]. Along with these previous studies, the results of our current study may be seen as a platform for future research investigating whether engagement in physical activity has a protective effect on LBP particularly when genetic and early-shared environmental influences are controlled for.

**Summary and conclusions**

Although females engaged in a sedentary lifestyle appear to be more likely to report LBP than those physically active, this association is not apparent when genetics and early environmental factors are accounted for, suggesting that genetics and environmental factors possibly influence this relationship. A sedentary lifestyle does not clearly increase the risk of developing persistent LBP, care-seeking due to LBP, and activity limiting LBP, although future studies with larger samples of twins discordant for comprehensive outcomes of LBP should be conducted to replicate these findings. We acknowledge that the small sample included in the co-twin analyses has yielded wide confidence intervals, caution should be exercised when interpreting, and a association may not be ruled out.

**Appendix**

**STROBE checklist**—items included and their location in the report are indicated in bold font.

<table>
<thead>
<tr>
<th>Item number</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title and abstract</strong></td>
<td>(a) Indicate the study’s design with a commonly used term in the title or the abstract (page 1, line 7). (b) Provide in the abstract an informative and balanced summary of what was done and what was found (page 1).</td>
</tr>
<tr>
<td><strong>Introduction</strong></td>
<td>Explain the scientific background and rationale for the investigation being reported (page 3 and 4).</td>
</tr>
<tr>
<td>Background/rationale</td>
<td>Objectives</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>State specific objectives, including any prespecified hypotheses (page 4, line 14).</td>
<td></td>
</tr>
<tr>
<td><strong>Methods</strong></td>
<td>Present key elements of study design early in the paper (page 5, line 3).</td>
</tr>
<tr>
<td>Study design</td>
<td>Setting</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
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<tr>
<td>Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection (page 5, line 7).</td>
<td></td>
</tr>
<tr>
<td>Participants</td>
<td>(a) Cohort study—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls. Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants (page 5 and 6). (b) Cohort study—For matched studies, give matching criteria and number of exposed and unexposed. Case-control study—For matched studies, give matching criteria and the number of controls per case.</td>
</tr>
<tr>
<td>Variables</td>
<td>Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable (page 6 to 8).</td>
</tr>
<tr>
<td>Data sources/measurement</td>
<td>8*</td>
</tr>
<tr>
<td>For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group (page 6 to 8).</td>
<td></td>
</tr>
<tr>
<td>Bias</td>
<td>Describe any efforts to address potential sources of bias (page 8).</td>
</tr>
<tr>
<td>Study size</td>
<td>Explain how the study size was arrived at (page 11 and 14).</td>
</tr>
<tr>
<td>Quantitative variables</td>
<td>Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why (page 9 and 10).</td>
</tr>
<tr>
<td>Statistical methods</td>
<td>(a) Describe all statistical methods, including those used to control for confounding (page 8 to 10). (b) Describe any methods used to examine subgroups and interactions (page 10). (c) Explain how missing data were addressed (page 9). (d) Cohort study—If applicable, explain how loss to follow-up was addressed. Case-control study—If applicable, explain how matching of cases and controls was addressed. Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy (page 10). (e) Describe any sensitivity analyses (page 10).</td>
</tr>
</tbody>
</table>

* Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
References


[34] Nuzzo R. P values, the “gold standard” of statistical validity, are not as reliable as many scientists assume. Nature 2014;506:150–2.


