BMJ Open Sport & Exercise Medicine

Are reallocations of time between physical activity, sedentary behaviour and sleep associated with low back pain? A compositional data analysis

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To cite: Kastelic K, Šarabon N, Stanford T, *et al*. Are reallocations of time between physical activity, sedentary behaviour and sleep associated with low back pain? A compositional data analysis. *BMJ Open Sport & Exercise Medicine* 2023;**9**:e001701. doi:10.1136/bmjsem-2023-001701

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bmjsem-2023-001701).

Accepted 31 October 2023

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ABSTRACT

Objectives The aim of this cross-sectional study was to explore the associations of reallocating time between moderate- to vigorous-intensity physical activity (MVPA), light-intensity physical activity (LPA), sedentary behaviour (SB) and sleep with occurrence, frequency and intensity of low back pain (LBP) among adults using compositional isotemporal substitution analysis.

Methods A total of 2333 participants from the general adult population completed the Daily Activity Behaviours Questionnaire asking about their time-use composition consisting of sleep, SB, LPA and MVPA, and they self-reported their frequency and intensity of LBP in the past year.

Results Regression analyses adjusted for age, sex, body mass index, smoking, stress, education and socioeconomic status found that the time-use composition is associated with the frequency (p=0.009) and intensity of LBP (p<0.001). Reallocating time from SB or LPA to sleep was associated with lower frequency and intensity of LBP (p<0.05). Reallocating time from MVPA to sleep, SB or LPA and from SB to LPA was associated with a lower intensity of LBP (p<0.05). For example, reallocating 30 min/day from SB to sleep was associated with 5% lower odds (95% CI: 2% to 8%, p=0.001) of experiencing LBP more frequently, and 2% lower LBP intensity (95% CI: 1% to 3%, p<0.001).

Conclusion LBP sufferers may benefit from getting additional sleep and spending more time in LPA, while engaging less in SB and MVPA. These reallocations of time may be meaningful from clinical and public health perspectives.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Very little is known on how reallocations of time between physical activity, sedentary behaviour (SB) and sleep are associated with low back pain (LBP).

WHAT THIS STUDY ADDS

⇒ Reallocating time from SB or light-intensity physical activity (LPA) to sleep is favourably associated with frequency and intensity of LBP.
⇒ Reallocating time from moderate- to vigorous-intensity physical activity (MVPA) to LPA, SB or sleep is favourably associated with intensity of LBP.
⇒ Reallocating time from SB to LPA is favourably associated with intensity of LBP.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our novel findings support self-management strategies for LBP that aim to increase sleep duration and LPA at the expense of MVPA and SB.

INTRODUCTION

Low back pain (LBP) is usually defined as pain, muscle tension or stiffness localised below the costal margin and above the inferior gluteal folds.[1] It is the most common musculoskeletal disorder and the leading cause of years lived with disability globally.[2] Chronic LBP has adverse effects on well-being and quality of life,[3] and it is associated with a significant economic burden. The estimated annual direct and indirect costs of LBP are up to $868 per capita.[4] From a public health perspective, it is therefore important to investigate risk factors for LBP.

The aetiology of LBP is still not well understood. As many as 95% of LBP cases are of unknown medical cause.[5] Most people experience LBP for the first time before they enter early adulthood,[6] and most LBP sufferers repeatedly experience LBP after its first occurrence.[7] Studies have shown that the intensity of LBP fluctuates over time, and this may include pain free periods.[8] Given that LBP is often a persistent condition, there is a need to investigate strategies that may help in its management.

In recent years, self-management strategies for LBP have been increasingly prioritised. For example, clinical practice guidelines for the management of non-specific LBP include recommendations to avoid bed rest, stay active and engage in structured exercise.[9 10] More recently, maintaining healthy sleep habits was also highlighted as an important lifestyle strategy for the management of LBP.[11] It should be noted that these guidelines do not include specific, practical instructions on how to achieve the recommendations. They also do not include quantitative recommendations on the duration of physical activity, sedentary behaviour (SB) and sleep. The reason for this may be a lack of evidence on the optimal balance between the three movement behaviours in this specific population group.

Epidemiological studies have found favourable associations of engaging in physical activity,[12] reducing SB[13] and getting adequate sleep[14] with LBP. However, such studies have generally examined each of these 24-hour movement behaviours in isolation, while ignoring or inadequately addressing their codependency.[15] The codependency of physical activity, SB and sleep stems from the fact that their durations always add up to 24 hours per day, which means that time spent in one of the behaviours can only be increased at the expense of one or both of the remaining behaviours. To enable the examination of how reallocations of time between physical activity, SB and sleep are associated with health outcomes, while adequately addressing codependency of these behaviours, recent methodological papers have recommended the use of compositional data analysis (CoDA).[15 16]

Therefore, the aim of this study was to explore the associations of reallocating time between moderate- to vigorous-intensity physical activity (MVPA), light-intensity physical activity (LPA), SB and sleep with occurrence, frequency and intensity of LBP among adults using CoDA. We hypothesised that reallocating SB and LPA to MVPA or sleep will be favourably associated with LBP.

Table 1 Participant characteristics (total sample, n=2333; LBP sufferers, n=1660)

Characteristic	n (%)* Total sample	LBP sufferers
Age		
18–44 years	896 (38)	598 (36)
45–64 years	1153 (49)	860 (52)
65+ years	284 (12)	202 (12)
Sex		
Female	1731 (74)	1225 (74)
Male	602 (26)	435 (26)
Body mass index		
Underweight (<18.5 kg/m^2)	44 (2)	28 (2)
'Normal' weight (18.5 to <25 kg/m^2)	1309 (56)	898 (54)
Overweight or obesity (≥25 kg/m^2)	980 (42)	734 (44)
Smoking status		
Smoker	404 (17)	296 (18)
Non-smoker	1929 (83)	1364 (82)
Experiencing stress		
Occasionally, very rarely or never	1505 (65)	1033 (62)
Often or every day	828 (35)	627 (38)
Education		
Primary or secondary education	687 (30)	529 (32)
Higher education	1646 (70)	1131 (68)
Socioeconomic status		
Low or very low	236 (10)	189 (11)
Middle	1820 (78)	1299 (78)
High or very high	277 (12)	172 (10)
LBP occurrence in the past year		
Yes	1600 (71)	1660 (100)
No	733 (29)	0 (0)
Frequency of experiencing LBP		
1–7 days	/	760 (46)
8–30 days	/	451 (27)
31–90 days	/	146 (9)
90+ days, but not every day	/	203 (12)
Every day	/	100 (6)
Intensity of LBP	M (IQR)†	
Average intensity	/	30 (19, 49)
24-hour movement behaviours	g (%)‡	
MVPA (min/day)	27 (2)	27 (2)
LPA (min/day)	499 (35)	502 (35)
SB (min/day)	440 (31)	438 (30)
Sleep (min/day)	474 (33)	473 (33)

*Absolute frequency (percentage).
†Median (IQR).
‡Compositional mean (percent of the day).
LBP, low back pain; LPA, light-intensity physical activity; MVPA, moderate- to vigorous-intensity physical activity; SB, sedentary behaviour.

METHODS

Participants and study design

Our cross-sectional sample (n=2333) included adults aged 18 years and over (table 1). Adults were invited to participate in the study via social media, web-portals, mailing lists and daily newspapers in Slovenia (from November 2019 to March 2020). Participants provided self-reported data via a web-based survey that included questions on sociodemographics, health-related lifestyle (including physical activity, SB and sleep) and LBP outcomes. The study was conducted in accordance with the Declaration of Helsinki and was approved by the National Ethics Committee (Republic of Slovenia National Medical Ethics Committee, ref: 0120-557/2017/4). All participants provided an online informed consent to participate in the study. There has been no patient and public involvement in research methods. This paper was written according to the Strengthening the Reporting of Observational Studies in Epidemiology checklist for cross-sectional studies.[17]

Measures

Physical activity, SB and sleep

Data on physical activity, SB and sleep were collected using the Daily Activity Behaviours Questionnaire (DABQ).[18]

This 32-item questionnaire asks about sleep and domain specific (including occupational, commuting and other non-occupational) physical activity and SB in the past 7 days. Average daily durations of MVPA, LPA, SB and sleep were calculated. The MVPA, LPA, SB and sleep estimates derived from DABQ have acceptable validity against device-based estimates (r=0.38–0.66) and test–retest reliability (ICC=0.59–0.65).[18]

Low back pain

Participants were asked about LBP frequency using the question "On how many days have you experienced low back pain in the last 12 months?", and they could choose between the following response options: '0 days'; '1–7 days'; '8–30 days'; '31–90 days'; 'more than 90, but not every day'; 'every day'.[19] The responses to this question were used to categorise participants as either 'LBP sufferer' (ie, any response other than 0 days) or 'non-sufferer' (ie, 0 days),[6] that is, to assess the occurrence of LBP in the past year. The full scale of responses to this question was used to examine the frequency of experiencing LBP in the subgroup of LBP sufferers. The subgroup of LBP sufferers was further asked about LBP intensity using the question "How would you rate the average intensity of your low back pain during the last 12 months (average pain intensity on days when you experienced pain)?" Participants provided their responses using a Visual Analogue Scale (VAS) ranging from 'no pain' to 'worst pain imaginable' (range of scores: from 0 to 100).[20]

Sociodemographic and lifestyle characteristics

The following data on sociodemographic and lifestyle characteristics were collected: sex (*M/F*); age (*18–44 years/45–64 years/65+ years*); socioeconomic status (*high or very high/middle/low or very low*); education (*primary or secondary education/higher education*); body mass index (BMI) (*underweight* ($<18.5\,kg/m^2$)*/'normal' weight* (18.5 *to* $<25\,kg/m^2$)*/overweight or obese* ($\geq 25\,kg/m^2$)) calculated from self-reported body height (*cm*) and body weight (*kg*); smoking status (*smoker/non-smoker*) and the frequency of experiencing stress (*often or every day/occasionally, very rarely or never*). Age and BMI were categorised to account for their possibly non-linear relationships with the outcome variable. The questions on sociodemographic and lifestyle characteristics were adapted from the National Health Survey.[21]

Statistical analysis

Statistical analysis was conducted using R V.4.2.2, RStudio, with the aid of 'tidyverse' packages and the packages 'boot', 'car', 'compositions', 'foreach', 'GGally', 'knitr', 'mice', 'performance' and 'zCompositions'. Participant characteristics were presented as absolute and relative frequencies (for categorical data), as medians and IQRs (for non-symmetrically distributed continuous data), and as compositional means (for compositional data).

We used CoDA to examine the associations of MVPA, LPA, SB and sleep with LBP outcomes. First, the log-ratio expectation-maximisation algorithm was used to replace zeros for 159 participants in the dataset with small positive values.[22] This was followed by calculating isometric log ratio coordinates (*ilrs*) from the MVPA, LPA, SB and sleep data. The *ilrs* were then entered as independent variables in the following regression models: (1) binary logistic regression with the occurrence of LBP (ie, 'LBP sufferer' vs 'non-sufferer') as the dependent variable; (2) ordinal logistic regression with the frequency of experiencing LBP (among LBP sufferers) as the ordinal dependent variable and (3) negative binomial regression with the intensity of LBP (among LBP sufferers) as the dependent variable. Model diagnostics were performed using: (1) the binned residual plot for the binary logistic regression; (2) model coefficient stability when fitting successive logistic regressions using a dichotomised version of the ordinal outcome variable (using different level of the ordinal outcome as the threshold) to check the proportional odds assumption for the ordinal logistic regression and (3) a likelihood ratio test for overdispersion as well as checking for influential observations and homoscedasticity of the deviance residuals for the negative binomial regression. All analyses were adjusted for age, sex, BMI, smoking, stress, education and socioeconomic status.

For outcomes with significant ($p<0.05$) associations with 24-hour movement behaviours, we also performed compositional isotemporal substitution analyses.[23] Calculations were done for reallocations of time between each pair of movement behaviours (while keeping the remaining behaviours constant), in increments of 10, 20 and 30 min from the mean composition (ie, 27, 502, 438 and 473 min/day spent in MVPA, LPA, SB and sleep, respectively, where reallocation would not result in infeasible compositions, that is, negative time in a given behaviour). In the isotemporal substitution analysis with LBP frequency as the ordinal outcome variable, we calculated: (1) the predicted OR contribution of the mean time-use composition and (2) the predicted OR contribution for each hypothetical time-use composition representing a given reallocation of time. We then calculated a ratio of the latter and the former. A ratio of these ORs that is higher than 1.0 indicates that the respective reallocation of time is associated with higher odds of experiencing LBP more frequently, and vice versa. In the isotemporal substitution analysis with LBP intensity as the outcome variable, we calculated: (1) the predicted mean LBP intensity for the mean time-use composition and (2) the predicted mean LBP intensity for each hypothetical time-use composition representing a given reallocation of time. We then calculated a ratio of the latter and the former. A ratio of these predicted values that is higher than 1.0 indicates that the respective reallocation of time is associated with a higher average LBP intensity, and vice versa. The Wald method was used to approximate 95% CIs for the ordinal logistic regression predictions (on the log-odds scale), and bootstrapping (R=1000) was used to compute the 95% CIs for the model based on negative binomial regression.

RESULTS

Most participants were females, non-smokers, highly educated and of middle socioeconomic status (table 1). Approximately half of participants were middle-aged adults and had overweight or obesity. The compositional mean of time spent in MVPA, LPA, SB and sleep were 27, 499, 440 and 474 min/day, respectively. The prevalence of LBP in the past year was 71%. Most of the participants who reported LBP (ie, LBP sufferers) experienced it on less than 31 days in the past year. Their median intensity of LBP in the past year was 30 (IQR: 19–49) on a 0–100 VAS.

We found associations of the 24-hour movement behaviours with frequency (χ^2_3 = 11.5, p=0.009) and intensity of LBP (χ^2_3 = 24.0, p<0.001) but not with the occurrence of LBP (χ^2_3 = 1.4, p=0.709). The negative binomial regression was used to explore the associations with intensity of LBP because it provided a better fit than multiple linear (with and without outcome transformation), Poisson and Beta regression models.

Among the LBP sufferers, reallocating time from SB or LPA to sleep was associated with lower odds of experiencing LBP more frequently (figure 1). The reallocations of time in the opposite direction were associated with higher odds of experiencing LBP more frequently. For example, reallocating 30 min/day from SB to sleep was associated with a 5% lower odds (ratio of ORs=0.95, 95% CI: 0.92 to 0.98, p=0.001) of experiencing LBP more frequently.

Among the LBP sufferers, reallocating time from SB or LPA to sleep also was associated with lower average LBP intensity (figure 2 and online supplemental file 1). The reallocations of time in the opposite direction were associated with a higher average LBP intensity. For example, reallocating 30 min/day from sleep to SB was associated with on average 2% higher LBP intensity (ratio of LBP intensity=1.02, 95% CI: 1.01 to 1.03, p<0.001). Reallocating time from MVPA to sleep, SB or LPA and from SB to LPA was also associated with lower average LBP intensity, while the reallocations of time in the opposite direction were associated with a higher average LBP intensity. For example, reallocating 20 min/day from MVPA to sleep was associated with on average 6% lower LBP intensity (ratio of LBP intensity=0.94, 95% CI: 0.91 to 0.97, p<0.001).

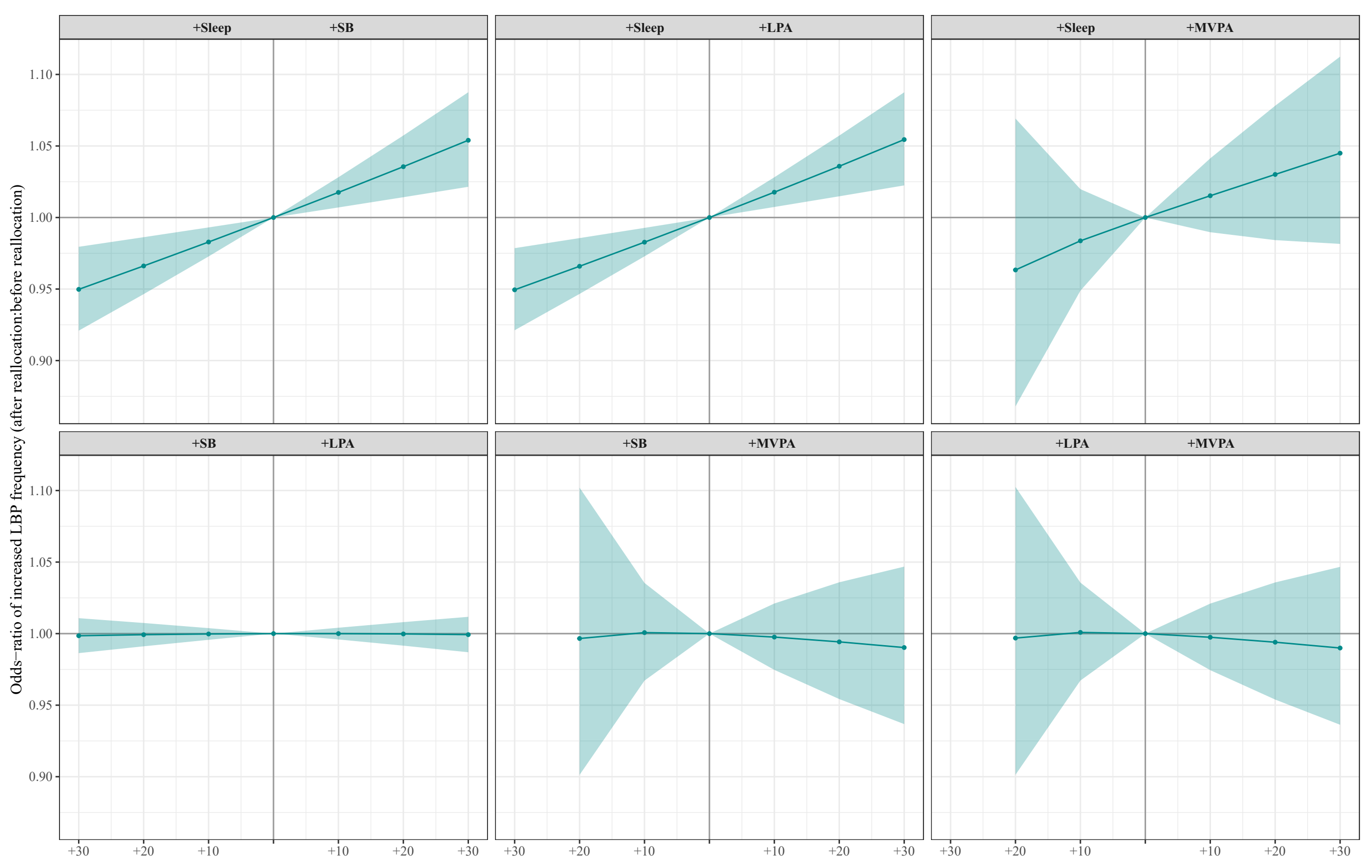

Figure 1 Associations of reallocating between 24-hour movement behaviours with the frequency of experiencing low back pain (n=1660). The analyses were adjusted for age, sex, body mass index, smoking, stress, education and socioeconomic status. LBP, low back pain; LPA, light-intensity physical activity; MVPA, moderate- to vigorous-intensity physical activity; SB, sedentary behaviour.

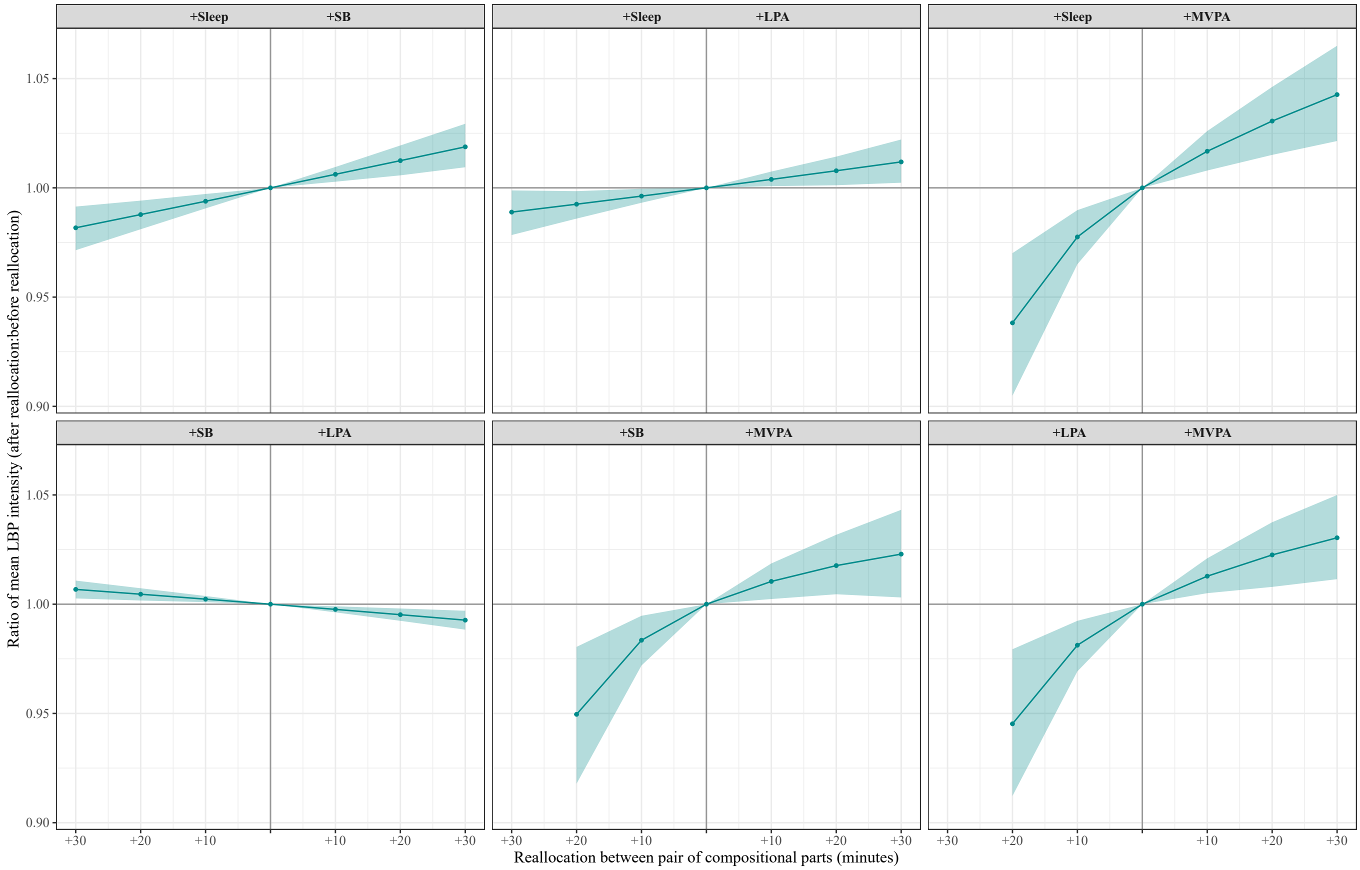

Figure 2 Associations of reallocating time between 24-hour movement behaviours with the intensity of low back pain (n=1660). The analyses were adjusted for age, sex, body mass index, smoking, stress, education and socioeconomic status. LBP, low back pain; LPA, light-intensity physical activity; MVPA, moderate- to vigorous-intensity physical activity; SB, sedentary behaviour.

DISCUSSION

The key finding of this study is that the time-use composition consisting of sleep, SB, LPA and MVPA was associated with the frequency and intensity of LBP. Specifically, our compositional isotemporal substitution analyses showed that: (1) reallocating time from SB or LPA to sleep is associated with lower frequency and intensity of LBP; (2) reallocating time from MVPA to any of the remaining 24-hour movement behaviours and from SB to LPA is associated with lower average LBP intensity and (3) reallocations of time in the opposite directions were associated with unfavourable LBP outcomes. These reallocations of time may be meaningful from clinical and public health perspectives.

The favourable associations of reallocating time to sleep with the frequency and intensity of LBP found in our study are in accordance with findings of previous studies that did not use CoDA.[14 24] This suggests that LBP sufferers may benefit from getting additional sleep, and that the potential importance of sleep for the management of LBP should be considered when developing and/or updating clinical guidelines. Our finding also supports the recommendation concerning sleep that has recently been included in the Australian clinical guidelines for the management of LBP.[11] According to our analyses, additional sleep time was associated with relatively small differences in LBP (1–6% lower LBP intensity for 30 min/day higher sleep time). However, even small differences can have an important impact, especially at the population level.[25] It should be noted that the predictions were made from the mean composition with 7.9 hours/day of sleep, which is already within the recommended duration for adults (ie, 7–9 hours/day).[26] It might be that the associations between reallocations of time to sleep and LBP outcomes would be stronger among individuals whose sleep duration is insufficient.

Our finding that MVPA was unfavourably associated with the intensity of LBP might be seen as inconsistent with the previous literature showing a beneficial association between physical activity and LBP.[12 27 28] However, most previous literature reporting a favourable relationship has focused only on leisure-time MVPA,[12 27 28] while little is known about the relative contribution of total MVPA (ie, MVPA as part of work, transportation, leisure and household) to LBP. Previous literature on occupational and household MVPA has usually reported unfavourable relationships with LBP.[28 29] Similarly, a recent study that used CoDA and included LBP sufferers found that reallocating time to leisure-time MVPA was associated with a lower risk of long-term sickness absence, while reallocating time to occupational MVPA was associated with a higher risk.[30] Given that MVPA in our study included all domains, it may be that unfavourable association between MVPA as part of work and LBP[28–30] dominated over favourable association between leisure-time MVPA and LBP.[12 27 28] Our findings challenge the general advice to be physically active to decrease the severity of LBP and support the provision of more specific recommendations with the distinction between different domains and intensities of physical activity. Future studies in time-use epidemiology are needed to explore the relative importance of domain-specific MVPA on a variety of LBP outcomes (eg, intensity, disability, chronicity).

Our finding that reallocating time to LPA (from other wake-time behaviours) was favourably associated with the intensity of LBP (and vice versa) is in accordance with previous research.[13 31] For example, a study that used CoDA found that reallocating time from SB to standing and walking (two common types of LPA) was associated with a lower intensity of LBP.[31] Furthermore, according to our analyses, additional time spent in LPA was associated with relatively small differences in LBP intensity (1–6% lower LBP intensity for 30 min/day higher LPA). It seems that substantially larger reallocations of time towards LPA would be needed to observe a clinically meaningful difference in LBP. Given that both SB and LPA usually constitute a large proportion of daily time (in our sample each of the two behaviours constituted around 30% of daily time), such large reallocations from SB to LPA might be feasible for LBP sufferers.

We did not find a significant association between the 24-hour movement behaviour composition and the occurrence of LBP, which is in accordance with one previous study that used CoDA and reported no statistically significant differences in MVPA, LPA, standing, SB and time in bed between LBP sufferers and their asymptomatic peers.[30] However, previous reviews have shown that short sleep is associated with an increased risk of LBP.[32] Some (but not all) previous reviews have also suggested that low MVPA[33] and high SB[34] are associated with increased risk of LBP. Our findings may differ from previous findings due to differences in the definition of LBP or differences in the sample demographics. In our study, LBP was defined as experiencing LBP on at least one occasion in the past year, while, for example, some previous studies were focused exclusively on 'clinically relevant' LBP.[32 33]

The differences associated with isotemporal substitutions were either pointing in the same direction for both frequency and intensity of LBP, or at least one of the two relationships was not statistically significant. Given that a non-significant relationship is not evidence of no relationship (the statistical inference tests only allow us to reject the null hypothesis but not to accept it), none of the relationships can be considered as 'conflicting'. Nevertheless, it is interesting that all types of isotemporal substitutions were significantly associated with the intensity of LBP, while only 4 out of 12 possible types of isotemporal substitutions were significantly associated with the frequency of LBP. The reason for this might be the difference in the sensitivity of the response scales used to assess these two outcome variables. While the frequency of LBP was assessed on a 6-point ordinal scale, the intensity of LBP was assessed on a scale from 0 to 100. Future studies should consider alternative options for assessing LBP frequency, as this may affect the findings on its relationships with movement behaviours.

Strengths and limitations

The key strengths of this study were as follows: (1) a relatively large sample of LBP sufferers and (2) the use of CoDA in accordance with the recent methodological developments in the field of time-use epidemiology. The study also had some limitations. First, due to the cross-sectional design of the study, we could not draw conclusions about causality. Movement behaviours can influence LBP, but it can also be that LBP influences movement behaviours, or that the relationship is bidirectional.[35] Second, our hypothetical reallocations of time were performed around the mean composition in our sample. It may be that the findings would be different in study populations with a different mean composition. Also, predictions from our reallocation analysis cannot be generalised to clinical LBP populations, because our study was conducted among participants from the general adult population, most of whom did not have clinically important LBP. Third, reliability of physical activity, SB and sleep estimates is generally somewhat lower when assessed by questionnaires, compared with device-based measures.[36 37] Imperfect reliability of physical activity, SB and sleep estimates may have attenuated their relationships with the measures of LBP in our study. This means that the true relationships between physical activity, SB and sleep with LBP are likely to be stronger than the ones found in our study. Fourth, there was a mismatch between the reference period for the assessment of LBP (ie, prior year) and movement behaviours (past week). For some participants, it is possible that the periods of their LBP were preceded by or coincided with a time-use composition that is very different from the one recorded in our study. However, past week is a common reference period in the assessment of movement behaviours using self-reports[38] and accelerometers,[36 37] because assessing movement behaviours across 1 week may provide valid estimates of individual's habitual activity.[39] Fifth, DABQ can be used to assess not just overall but also domain-specific physical activity and SB. However, only 10% of our participants reported engaging in occupational MVPA and the rest of the sample reported 0 min/day of occupational MVPA. The compositional isotemporal substitution analysis cannot be used if the composition includes zeros.[22] While zero replacement methods are available,[22] the use of imputation methods is generally not recommended if the proportion of zeros in the dataset is very high, as in our study.[40]

CONCLUSIONS

The time-use composition consisting of sleep, SB, LPA and MVPA was associated with the frequency and intensity of LBP. Specifically, reallocating time from SB or LPA to sleep was associated with lower frequency and intensity of LBP, while reallocating time from MVPA to any of the remaining 24-hour movement behaviours and from SB to LPA was associated with a lower intensity of LBP. Our findings generally suggest that spending more time sleeping and in LPA while spending less time in MVPA and SB could be considered as self-management strategies for LBP. Future longitudinal and experimental studies using compositional isotemporal substitution analysis among various populations are needed to better understand the importance of movement behaviours in the self-management of LBP.

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Acknowledgements The authors gratefully acknowledge the European Commission for funding the InnoRenew CoE project (Grant Agreement #739574) under the Horizon2020 Widespread-Teaming program and the Republic of Slovenia (Investment funding of the Republic of Slovenia and the European Union of the European Regional Development Fund). The authors also acknowledge the Slovenian Research and Innovation Agency for funding the infrastructure group at the University of Primorska (research core funding No IO-0035). The authors are very grateful to Michael David Burnard (MDB) for his contributions to this study. This article is a part of the PhD project of the first author, KK, supervised by MDB (associate supervisor), NŠ (associate supervisor) and ŽP (principal supervisor).

Contributors KK and NŠ conceptualised the study. KK processed the data and drafted the initial version of the manuscript. TS conceptualised and carried out statistical analysis and contributed to interpretation of results and drafting the manuscript. ŽP and DD contributed to conceptualising the data analysis, interpretation of results and drafting the manuscript. All authors reviewed all versions of the manuscript and contributed intellectually to its content. KK is a guarantor for this study.

Funding DD was supported by the Australian National Health and Medical Research Council (NHMRC) Early Career Fellowship GNT1162166 and by the Centre of Research Excellence in Driving Global Investment in Adolescent Health funded by NHMRC GNT1171981. DD, ŽP and TS were partially supported by the NHMRC Ideas grant 'Optimising time use for health and wellbeing' (ref: GA65852).

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The study was conducted in accordance with the Declaration of Helsinki and was approved by the National Ethics Committee (Republic of Slovenia National Medical Ethics Committee, ref: 0120-557/2017/4). All participants provided an informed consent to participate in the study. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Datasets and R code used in this study are available at https://github.com/tystan/backpaincoda.

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