Indirect effect of sleep on abdominal pain through daytime dysfunction in adults with irritable bowel syndrome

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The authors made the following contributions. Anthony Cifre: Conceptualization, Writing - Original Draft Preparation, Writing - Review & Editing.

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Abstract

Study Objectives: Sleep deficiency, psychological distress, daytime dysfunction, and abdominal pain are common in adults with irritable bowel syndrome. Prior research on individuals with chronic pain has identified the indirect effect of sleep on pain through psychological distress or daytime dysfunction; however, this effect is less clear in irritable bowel syndrome. The purpose of this study was to examine potential indirect effects of sleep on abdominal pain symptoms simultaneously through psychological distress and daytime dysfunction in adults with irritable bowel syndrome.

Methods: Daily symptoms of nighttime sleep complaints (sleep quality and refreshment), psychological distress, daytime dysfunction (fatigue, sleepiness, and difficulty concentrating), and abdominal pain were collected in baseline assessments from 2 randomized controlled trials of 332 adults (mean age 42 years and 85% female) with irritable bowel syndrome. Structural equation modeling was used to examine the global relationships among nighttime sleep complaints, psychological distress, daytime dysfunction, and abdominal pain.

Results: The structural equation modeling analyses found a strong indirect effect of poor sleep on abdominal pain via daytime dysfunction but not psychological distress. More than 95% of the total effect of nighttime sleep complaints on abdominal pain was indirect.

Conclusions: These findings suggest that the primary impact of nighttime sleep complaints on abdominal pain is indirect. The indirect effect appears primarily through daytime dysfunction. Such understanding provides a potential avenue to optimize personalized and hybrid behavioral interventions for adults with irritable bowel syndrome through addressing daytime dysfunction and sleep behaviors. Additional study integrating symptoms with biological markers is warranted to explore the underlying mechanisms accounting for these symptoms.

Keywords: irritable bowel syndrome, sleep, pain, daytime dysfunction, psychological

distress

Word count: X

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Methods

We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study.

Participants

Material

Procedure

Data analysis

```
## lavaan 0.6.14 ended normally after 249 iterations
##
##   Estimator                                         ML
##   Optimization method                           NLMINB
##   Number of model parameters                        30
##
##   Number of observations                           332
##
## Model Test User Model:
##
##   Test statistic                               173.087
##   Degrees of freedom                                48
##   P-value (Chi-square)                           0.000
##
```

```
## Parameter Estimates:
##
##   Standard errors                           Standard
##   Information                               Expected
##   Information saturated (h1) model          Structured
##
## Latent Variables:
##                           Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   abdominal_discomfort =~
##     ab_pain                  1.000                               23.044    0.886
##     ab_pain_aftr_t           0.997    0.048   20.925    0.000   22.966    0.884
##     ab_dist                  1.067    0.062   17.132    0.000   24.585    0.774
##     intest_gas               0.866    0.063   13.693    0.000   19.966    0.665
##   nightime_sleep =~
##     dim_sleep_qual           1.000                               23.921    0.881
##     unrefresh_slep           1.041    0.087   11.998    0.000   24.912    0.919
##   day_dysfunction =~
##     fatigue                  1.000                               24.987    0.918
##     sleepiness_day           0.921    0.040   22.824    0.000   23.015    0.894
##     hard_concent             0.575    0.038   15.035    0.000   14.369    0.693
##   psych_distress =~
##     anxiety                  1.000                               19.303    0.863
##     stress                   1.145    0.062   18.365    0.000   22.106    0.870
##     dep_mood                 0.649    0.041   15.682    0.000   12.519    0.759
##
## Regressions:
##                         Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
```

```
##   psych_distress ~
##     nightime_sleep          0.215    0.049    4.343    0.000    0.266    0.266
##   day_dysfunction ~
##     nightime_sleep          0.327    0.052    6.341    0.000    0.313    0.313
##     psych_distress          0.759    0.068   11.094    0.000    0.586    0.586
##   abdominal_discomfort ~
##     day_dysfunctin          0.445    0.080    5.561    0.000    0.483    0.483
##     nightime_sleep          0.038    0.059    0.650    0.516    0.040    0.040
##     psych_distress          0.091    0.093    0.977    0.328    0.076    0.076
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .ab_pain         145.553   18.979    7.669    0.000  145.553    0.215
##    .ab_pain_aftr_t  147.024   18.981    7.746    0.000  147.024    0.218
##    .ab_dist         405.029   37.289   10.862    0.000  405.029    0.401
##    .intest_gas      501.627   42.403   11.830    0.000  501.627    0.557
##    .dim_sleep_qual  164.290   44.995    3.651    0.000  164.290    0.223
##    .unrefresh_slep  114.302   47.630    2.400    0.016  114.302    0.156
##    .fatigue         115.979   19.106    6.070    0.000  115.979    0.157
##    .sleepiness_day  133.453   17.777    7.507    0.000  133.453    0.201
##    .hard_concent    223.624   18.923   11.818    0.000  223.624    0.520
##    .anxiety         128.105   16.616    7.710    0.000  128.105    0.256
##    .stress          156.572   21.218    7.379    0.000  156.572    0.243
##    .dep_mood        115.038   10.850   10.602    0.000  115.038    0.423
##    .abdmnl_dscmfrt  366.932   39.069    9.392    0.000    0.691    0.691
##     nightime_sleep  572.237   70.479    8.119    0.000    1.000    1.000
##    .day_dysfunctin  287.565   32.696    8.795    0.000    0.461    0.461
```

```
##    .psych_distress  346.157   37.471    9.238    0.000    0.929    0.929

## lavaan 0.6.14 ended normally after 326 iterations
##
##   Estimator                                         ML
##   Optimization method                           NLMINB
##   Number of model parameters                        30
##
##   Number of observations                           332
##
## Model Test User Model:
##
##   Test statistic                               173.087
##   Degrees of freedom                                48
##   P-value (Chi-square)                           0.000
##
## Model Test Baseline Model:
##
##   Test statistic                              2636.350
##   Degrees of freedom                                66
##   P-value                                        0.000
##
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                    0.951
##   Tucker-Lewis Index (TLI)                       0.933
##
## Loglikelihood and Information Criteria:
```

```
##
##   Loglikelihood user model (H0)             -17271.666
##   Loglikelihood unrestricted model (H1)     -17185.122
##
##   Akaike (AIC)                               34603.332
##   Bayesian (BIC)                             34717.486
##   Sample-size adjusted Bayesian (SABIC)      34622.325
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.089
##   90 Percent confidence interval - lower         0.075
##   90 Percent confidence interval - upper         0.103
##   P-value H_0: RMSEA <= 0.050                    0.000
##   P-value H_0: RMSEA >= 0.080                    0.848
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.050
##
## Parameter Estimates:
##
##   Standard errors                             Standard
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##
## Latent Variables:
```

```
##                          Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   abdominal_discomfort =~
##     ab_pain                 1.000                              23.044    0.886
##     ab_pain_aftr_t          0.997    0.048   20.925    0.000   22.966    0.884
##     ab_dist                 1.067    0.062   17.132    0.000   24.585    0.774
##     intest_gas              0.866    0.063   13.693    0.000   19.966    0.665
##   nightime_sleep =~
##     dim_sleep_qual          1.000                              23.921    0.881
##     unrefresh_slep          1.041    0.087   11.998    0.000   24.912    0.919
##   day_dysfunction =~
##     fatigue                 1.000                              24.987    0.918
##     sleepiness_day          0.921    0.040   22.824    0.000   23.015    0.894
##     hard_concent            0.575    0.038   15.035    0.000   14.369    0.693
##   psych_distress =~
##     anxiety                 1.000                              19.303    0.863
##     stress                  1.145    0.062   18.365    0.000   22.106    0.870
##     dep_mood                0.649    0.041   15.682    0.000   12.519    0.759
##
## Regressions:
##                          Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   abdominal_discomfort ~
##     nghtm_slp  (c)          0.038    0.059    0.650    0.516    0.040    0.040
##     psych_dst (b1)          0.091    0.093    0.977    0.328    0.076    0.076
##     dy_dysfnc (b2)          0.445    0.080    5.561    0.000    0.483    0.483
##   psych_distress ~
##     nghtm_slp (a1)          0.215    0.049    4.343    0.000    0.266    0.266
##   day_dysfunction ~
```

```
##     nghtm_slp (a2)          0.490    0.061    8.003    0.000    0.469    0.469
##
## Covariances:
##                      Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##  .day_dysfunction ~~
##    .psych_distress    262.755   31.409    8.366    0.000    0.640    0.640
##
## Variances:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .ab_pain         145.553   18.979    7.669    0.000  145.553    0.215
##    .ab_pain_aftr_t  147.024   18.981    7.746    0.000  147.024    0.218
##    .ab_dist         405.029   37.289   10.862    0.000  405.029    0.401
##    .intest_gas      501.627   42.403   11.830    0.000  501.627    0.557
##    .dim_sleep_qual  164.290   44.995    3.651    0.000  164.290    0.223
##    .unrefresh_slep  114.302   47.630    2.400    0.016  114.302    0.156
##    .fatigue         115.979   19.106    6.070    0.000  115.979    0.157
##    .sleepiness_day  133.453   17.777    7.507    0.000  133.453    0.201
##    .hard_concent    223.624   18.923   11.818    0.000  223.624    0.520
##    .anxiety         128.105   16.616    7.710    0.000  128.105    0.256
##    .stress          156.572   21.218    7.379    0.000  156.572    0.243
##    .dep_mood        115.038   10.850   10.602    0.000  115.038    0.423
##    .abdmnl_dscmfrt  366.932   39.069    9.392    0.000    0.691    0.691
##     nightime_sleep  572.237   70.479    8.119    0.000    1.000    1.000
##    .day_dysfunctin  487.012   48.452   10.051    0.000    0.780    0.780
##    .psych_distress  346.157   37.471    9.238    0.000    0.929    0.929
##
## R-Square:
```

```
##                    Estimate
##     ab_pain           0.785
##     ab_pain_aftr_t    0.782
##     ab_dist           0.599
##     intest_gas        0.443
##     dim_sleep_qual    0.777
##     unrefresh_slep    0.844
##     fatigue           0.843
##     sleepiness_day    0.799
##     hard_concent      0.480
##     anxiety           0.744
##     stress            0.757
##     dep_mood          0.577
##     abdmnl_dscmfrt    0.309
##     day_dysfunctin    0.220
##     psych_distress    0.071
##
## Defined Parameters:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     psych_dstr_IDE    0.019    0.020    0.955    0.340    0.020    0.020
##     dy_dysfnct_IDE    0.218    0.047    4.612    0.000    0.226    0.226
##     sumIDE            0.238    0.041    5.729    0.000    0.247    0.247
##     total             0.276    0.058    4.750    0.000    0.286    0.286
```

We used R (Version 4.2.2; R Core Team, 2022b) and the R-packages *car* (Version 3.1.1; Fox & Weisberg, 2019; Fox, Weisberg, & Price, 2022), *carData* (Version 3.0.5; Fox et al., 2022), *dplyr* (Version 1.1.0; Wickham, François, Henry, Müller, & Vaughan, 2023), *forcats* (Version 1.0.0; Wickham, 2023), *foreign* (Version 0.8.84; R Core Team, 2022a),

ggplot2 (Version 3.4.1; Wickham, 2016), *ggpubr* (Version 0.6.0; Kassambara, 2023a), *haven* (Version 2.5.1; Wickham, Miller, & Smith, 2022), *lavaan* (Version 0.6.14; Rosseel, 2012), *lme4* (Version 1.1.31; Bates, Mächler, Bolker, & Walker, 2015), *lmerTest* (Version 3.1.3; Kuznetsova, Brockhoff, & Christensen, 2017), *Matrix* (Version 1.5.3; Bates, Maechler, & Jagan, 2022), *pacman* (Version 0.5.1; Rinker & Kurkiewicz, 2018), *papaja* (Version 0.1.1; Aust & Barth, 2022), *purrr* (Version 1.0.1; Wickham & Henry, 2023), *readr* (Version 2.1.4; Wickham, Hester, & Bryan, 2023), *readxl* (Version 1.4.2; Wickham & Bryan, 2023), *rstatix* (Version 0.7.2; Kassambara, 2023b), *stringr* (Version 1.5.0; Wickham, 2022), *tibble* (Version 3.1.8; Müller & Wickham, 2022), *tidyr* (Version 1.3.0; Wickham, Vaughan, & Girlich, 2023), *tidyverse* (Version 1.3.2; Wickham et al., 2019), and *tinylabels* (Version 0.2.3; Barth, 2022) for all our analyses.

Results

Discussion

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