2020

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ABSTRACT

Disturbed sleep, defined as any alteration to normal sleep patterns, has been linked to poor cardiovascular health and an increase in cardiovascular disease (CVD) risk. These negative sleep patterns are highly prevalent with 35% to 41% of individuals in the United States reported some form of disturbed sleep. Although high amounts of physical activity (PA) are often associated with high sleep quality, little is known about PA's effectiveness to improve different aspects of sleep (e.g. duration vs quality) and the mechanisms to which it can improve sleep quality. **PURPOSE**: The study sought to determine the ability of increased PA to improve sleep efficiency in healthy young adults. **METHODS**: Nineteen young adults (25±4 yrs) were recruited for this study. Subjects wore an accelerometer (Actigraph GT3x-BT) for a total of three weeks to record daily physical activity (step count; moderate-to-vigorous physical activity (MVPA)) and sleep variables (total time in bed (TTB), sleep efficiency, wake after sleep onset (WASO), and total sleep time(TST)). Subjects maintained normal physical activity levels for the first week (BL), then increased their step count by an average of 5,000 steps/day across the next two weeks (W1 and W2). Heart rate variability (HRV) and venous blood draws were collected weekly to assess sympathetic activity and inflammation, respectively. **RESULTS**: The physical activity intervention resulted in significant increases ($p < 0.001$) in MVPA and step-count for both W1 (13163 ± 3184) and W2 (12168 ± 3619) when compared to BL (8648 ± 2615 steps/day). No significant differences from BL were observed when examining sleep efficiency (BL: 83.8 ± 6.4; W1: 85.5 ± 4.0; W2: 84.2 ± 6.1 %), sympathetic-vagal balance, and inflammatory marker concentrations in W1 and W2. A significant correlation was revealed when assessing the change in sleep efficiency from BL to W1 ($r = -0.81$, $p < 0.001$) when compared to initial sleep efficiency values. **CONCLUSION**: This study revealed that although young healthy individuals appear to lack improvements in sleep efficiency with an increase in physical activity, those who reported the lowest sleep quality had the greatest improvements in sleep efficiency following an increase in physical activity. Therefore, the findings of the study suggest that although increasing physical activity can improve sleep quality, a potential "ceiling effect" may occur, as when sleep quality is adequate, augmenting physical activity no longer has a substantial effect.

METHODS

Subjects

Nineteen recreationally active young adults (25 ±4 yrs) with no reported history of sleep disorders took part in this study.

Physical Activity Intervention

Subjects increased their step count by an average of 5,000 steps/day for the two weeks following BL measures. A pedometer (Omron HJ-321) was given to each subject to provide real-time, daily visual feedback of their step count.

Sleep Measures

Subjects wore an accelerometer (Actigraph GT3x-BT) for a total of three weeks. The accelerometer was worn on the right hip in the midline of the thigh during the day to record PA (step count and MVPA) and worn on the non-dominant wrist during night to record sleep (TTB, sleep efficiency, WASO, and TST).

Autonomic Nervous System and Inflammatory Markers

Five minutes of HRV was collected in the supine position after 10 minutes of rest. Venous blood draws were collected to measure inflammatory markers IL-6 and TNF-alpha using commercially available assay kits (R&D Systems, Minneapolis, MN, USA).

Statistical Analysis

A one-way ANOVA was employed for each normally distributed measure (step count, MVPA, TST, TNF-alpha). A Wilcoxon rank sum test was employed when data sets were not normally distributed (sleep efficiency, WASO, IL-6, LF/HF ratio). Subsequent post hoc analyses (Wilcoxon each pair and Tukey-HSD) were employed when a significant main effect was revealed. Pearson correlations were utilized to determine relationships between sleep variables and physical activity, inflammatory markers, and HRV measures. Level of significance for all tests was set a priori at $\alpha < 0.05$.

RESULTS

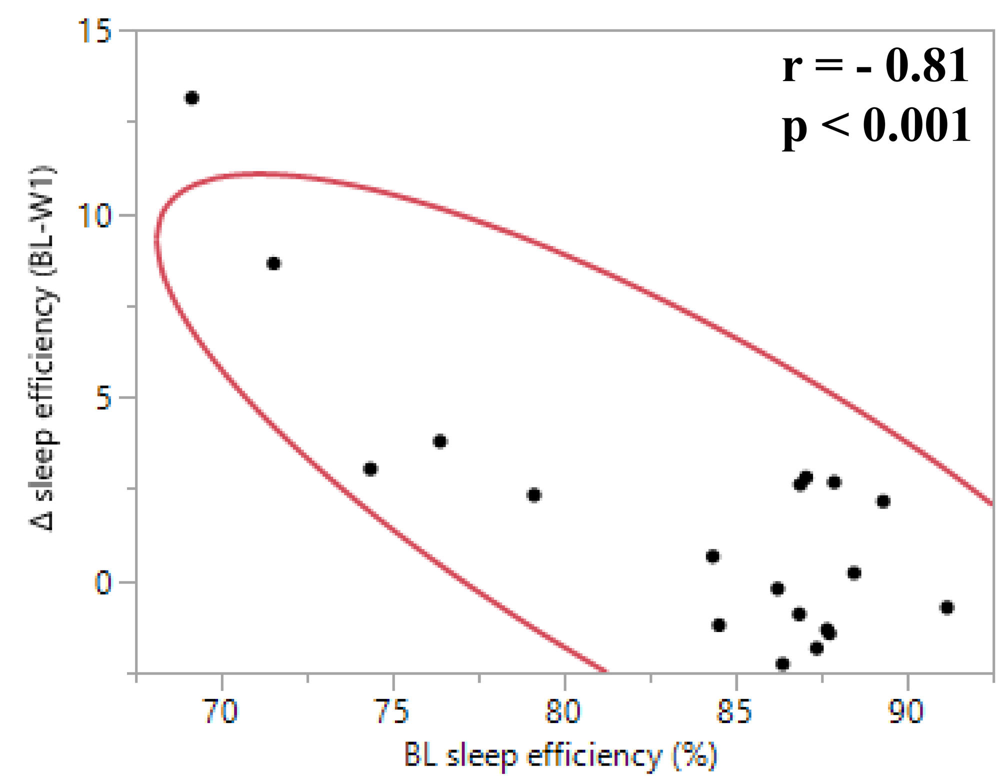

Figure 1: Association between BL sleep efficiency and the change in sleep efficiency from BL to W1. Density ellipse is set at 95% probability.

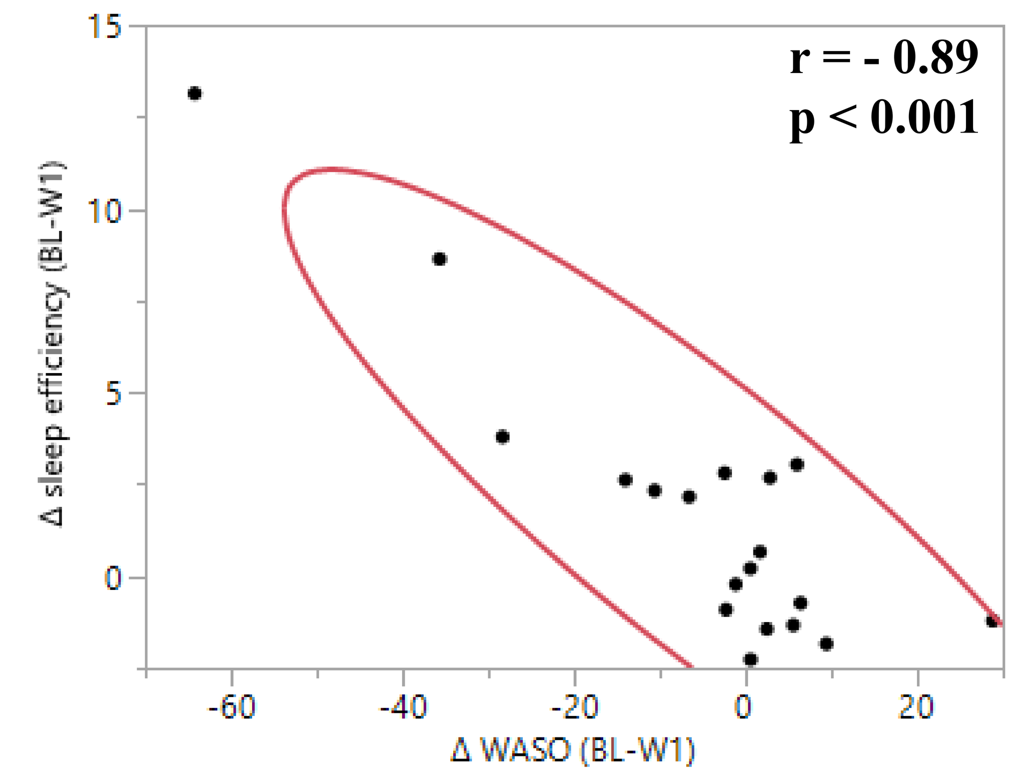

Figure 2: Association between the change in sleep efficiency and WASO from BL to W1. Density ellipse is set at 95% probability.

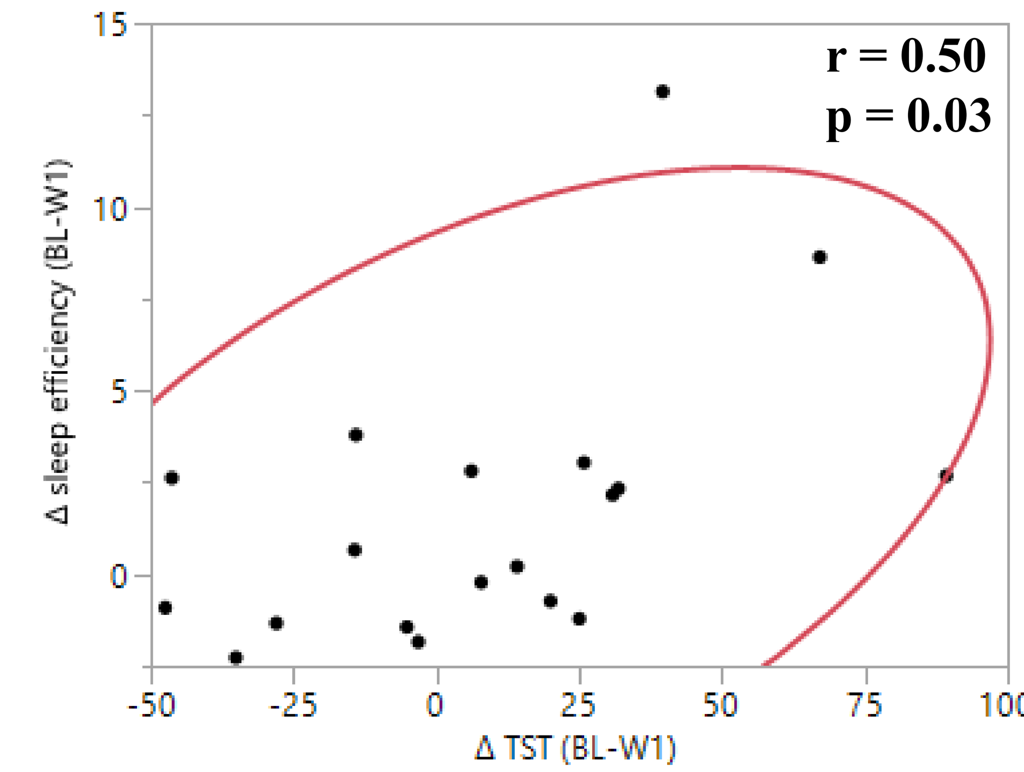

Figure 3: Association between the change in sleep efficiency and TST from BL to W1. Density ellipse is set at 95% probability.

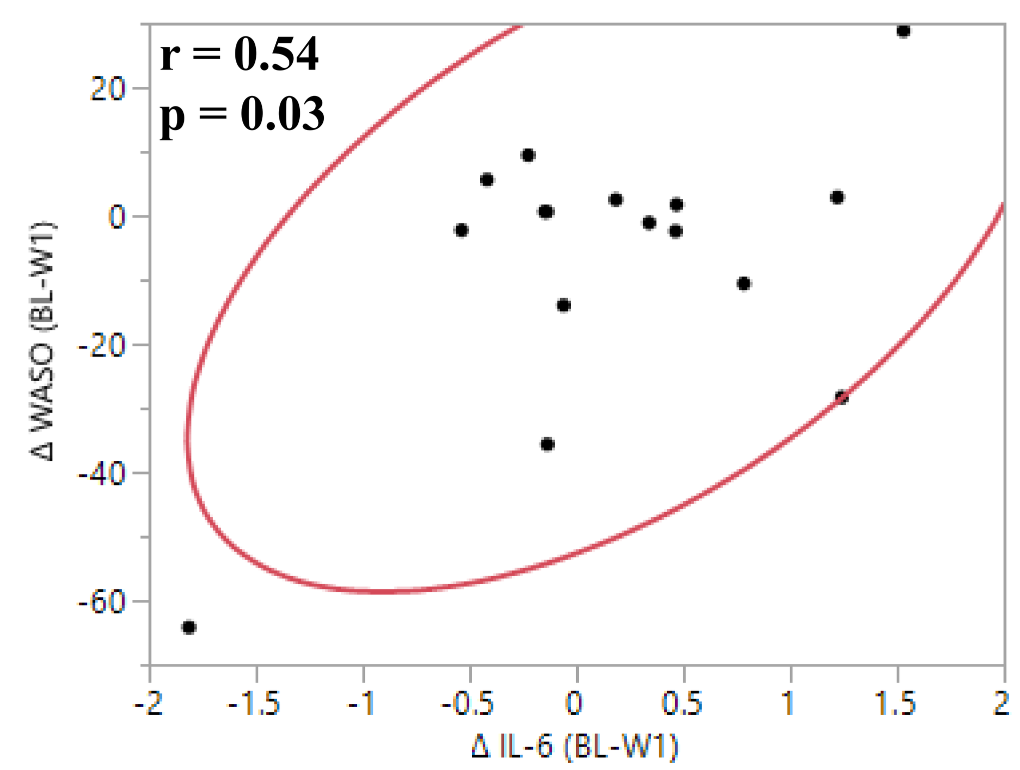

Figure 4: Association between the change in WASO and IL-6 concentration from BL to W1. Density ellipse is set at 95% probability.

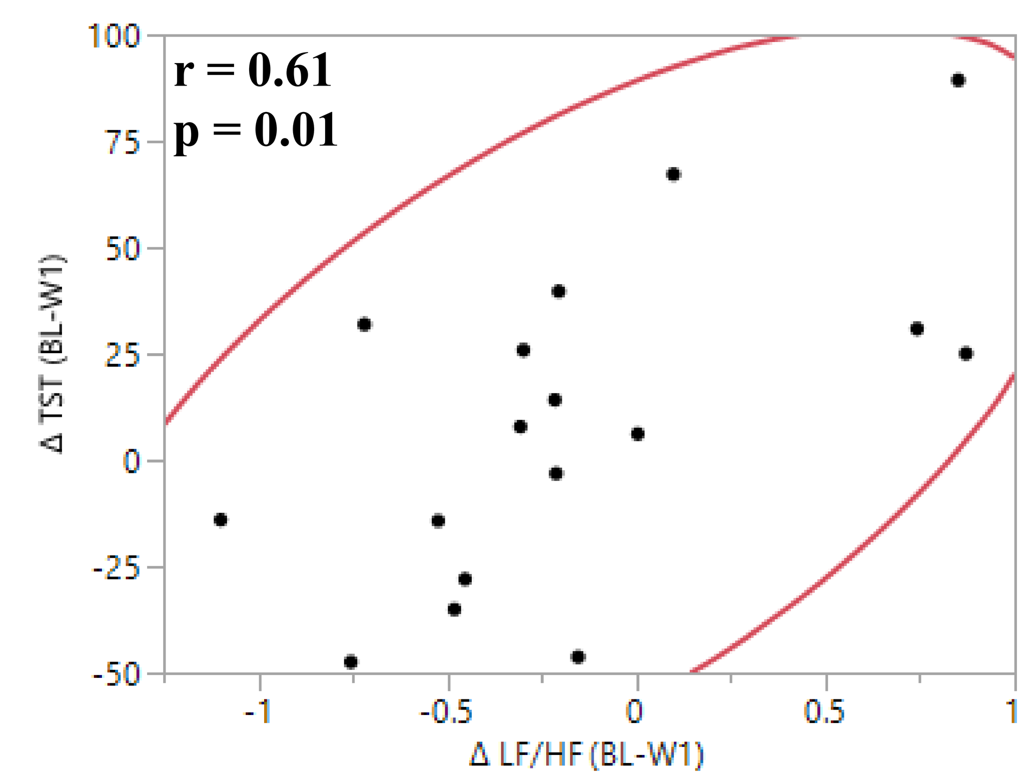

Figure 5: Association between the change in TST and LF/HF ratio from BL to W1. Density ellipse is set at 95% probability.

Table 1: Subject characteristics. (n = 19)

Subject Characteristics	Mean ± SD
Anthropometric Data	
Age (years)	25 ± 5
Weight (kilograms)	67 ± 12
Height (centimeters)	167 ± 8
BMI (kilograms/meters^2)	25 ± 3
Body Fat (%)	26 ± 10

Table 2: Physical activity, sleep, inflammation, and autonomic nervous system (ANS) measures across time [Mean ± SD or median (25th percentile, 75th percentile). * $p < 0.001$ vs BL].

Variable	BL	W1	W2
Physical Activity Measures			
Step count (average per day)	8648 ± 2615	13163 ± 3184*	12169 ± 3619*
MVPA (average minutes/day)	57 ± 26	93 ± 34*	89 ± 30*
Sedentary Time (avg minutes/day)	637 ± 91	615 ± 64	610 ± 59
Sleep Measures			
TTB (average minutes/night)	456 ± 55	455 ± 59	470 ± 69
Sleep efficiency (%)	87 (79, 88)	86 (82, 90)	84 (81, 90)
WASO (average minutes/night)	52 (43, 85)	61 (45, 72)	64 (45, 92)
TST (average minutes/night)	380 ± 59	389 ± 57	396 ± 63
Inflammation & ANS modulation			
IL-6 (picograms/milliliter)	0.75 (0.71, 1.16)	0.72 (0.60, 1.34)	0.76 (0.62, 0.83)
TNF-alpha (picograms/milliliter)	1.0 ± 0.40	0.93 ± 0.28	0.93 ± 0.33
Sympathetic-Vagal ratio	0.99 (0.5, 1.4)	0.7 (0.4, 1.2)	0.9 (0.3, 2.2)

CONCLUSIONS

- An increase in PA does not appear to improve sleep quality in healthy young adults (Table 2); however, those who reported the lowest sleep quality had the greatest improvements in sleep efficiency following an increase in PA (Figure 1).
- Improvements in sleep efficiency following an increase in PA were driven by a decrease in WASO (Figure 2) and an increase in TST (Figure 3).
- Improvements in WASO were associated with decreases in IL-6 (Figure 4), and improvements in TST were associated with increases in sympathetic nervous system activity (Figure 5).
- Taken together, increasing PA can improve sleep quality via decreases in inflammation and increases in sympathetic nervous system activity; however a potential "ceiling effect" may occur, as when sleep quality is adequate, augmenting PA no longer has a substantial effect.

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