Increased objectively assessed vigorous-intensity exercise is associated with reduced stress, increased mental health and good objective and subjective sleep in young adults

Markus Gerber ⁎, Serge Brand a,b, Christian Herrmann a, Flora Colledge a, Edith Holsboer-Trachsler b, Uwe Pühse a

a Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland
b Psychiatric Hospital of the University of Basel, Center for Affective, Stress and Sleep Disorders, Basel, Switzerland

HIGHLIGHTS
• Vigorous exercise has mental health benefits beyond moderate physical activity.
• Vigorous exercise is associated with less stress, pain, insomnia and depression.
• Vigorous exercisers have more favorable objective sleep pattern.
• Vigorous exercisers report fewer mental health problems if exposed to high stress.

ARTICLE INFO
Article history:
Received 25 March 2014
Accepted 30 May 2014
Available online 4 June 2014

Keywords:
Objective physical activity
Stress
Pain
Depressive symptoms
Sleep complaints
Objective sleep

ABSTRACT

The role of physical activity as a factor that protects against stress-related mental disorders is well documented. Nevertheless, there is still a dearth of research using objective measures of physical activity. The present study examines whether objectively assessed vigorous physical activity (VPA) is associated with mental health benefits beyond moderate physical activity (MPA). Particularly, this study examines whether young adults who accomplish the American College of Sports Medicine’s (ACSM) vigorous-intensity exercise recommendations differ from peers below these standards with regard to their level of perceived stress, depressive symptoms, perceived pain, and subjective and objective sleep. A total of 42 undergraduate students (22 women, 20 men; M = 21.24 years, SD = 2.20) volunteered to take part in the study. Stress, pain, depressive symptoms, and subjective sleep were assessed via questionnaire, objective sleep via sleep-EEG assessment, and VPA via actigraphy. Meeting VPA recommendations had mental health benefits beyond MPA. VPA was associated with less stress, pain, subjective sleep complaints and depressive symptoms. Moreover, vigorous exercisers had more favorable objective sleep pattern. Especially, they had increased total sleep time, more stage 4 and REM sleep, more slow wave sleep and a lower percentage of light sleep. Vigorous exercisers also reported fewer mental health problems if exposed to high stress. This study provides evidence that meeting the VPA standards of the ACSM is associated with improved mental health and more successful coping among young people, even compared to those who are meeting or exceeding the requirements for MPA.

© 2014 Elsevier Inc. All rights reserved.

1. Introduction

Stress and stress-related mental disorders are extremely common among young people [1,2]. Studies show that high levels of stress are associated with a plethora of mental health problems including increased depressive symptoms [3], higher burnout rates [4], augmented sleep complaints [5], elevated levels of pain [6], and decreased quality of life [7]. This is critical from a public health perspective because these mental health problems are highly prevalent among young people. For example, a recent review revealed that college students report depressive disorders more often than the general population with a mean occurrence rate of 31% [8]. Similar figures exist for other mental health problems such as sleep complaints with prevalence rates up to 50% [9,10]. Moreover, many of these disorders have a high temporal stability and persist over several years [11,12], leading to long-term bio-
physiological changes [13] that may increase the risk for cardiovascular diseases [14]. Finally, mental health problems are associated with decreased professional success [15], which is especially problematic for young people who are at the beginning or their careers.

Meanwhile, the role of physical activity as a factor that protects against stress-related mental disorders is well documented [16,17]. Previous studies have shown that young people who regularly engage in physical activity perceive less stress [18], report lower depressive symptoms [19], experience fewer sleep complaints [20,21], and perceive fewer symptoms of pain [6]. Researchers have also shown that regular physical activity can prevent mental health problems among people with high stress exposures [22,23].

Despite this body of evidence, there is still a dearth of research using objective measures of physical activity. With few exceptions [24,25], current knowledge is based on self-reported levels of physical activity. The present study goes beyond the existing literature in that (i) accelerometer data are used to examine the relationship between objectively measured physical activity, stress, depressive symptoms, pain and sleep complaints, (ii) current physical activity guidelines of the American College of Sports Medicine (ACSM) [26,27] are referenced to categorize participants into groups who do/do not accomplish vigorous physical activity (VPA) recommendations [26], (iii) subjective and objective measures are combined to assess sleep [28], and (iv) interactions between stress and physical activity are tested to investigate whether participants who accomplish current vigorous-intensity exercise guidelines cope more successfully with high levels of stress [23].

Importantly, this study does not compare active versus inactive individuals because all participants in this sample meet the ACSM’s moderate physical activity (MPA) standards (≥ 150 min of MPA). Rather, it compares those who engage only in MPA with those who engage in MPA and VPA. Thus, the specific focus of this study is whether – beyond basic MPA recommendations – meeting the ACSM’s vigorous-intensity exercise guidelines (≥ 3 × 20 min of VPA per week) is associated with additional mental health benefits among young people.

This specific focus is important because some scientists have argued that VPA might have greater health benefits than MPA [29–31] given that VPA is more effective in increasing aerobic fitness, and that energy expenditure rates are higher for VPA. These assumptions were supported in several investigations using mortality and physical disease indicators [32–38]. For example, Lee and Paffenbarger [39] found in a 15 year longitudinal study with 13,485 men (Mage = 58 years) that VPA clearly predicted lower mortality, whereas light physical activity (LPA: < 4 METS) did not result in reduced mortality rates. Comparable results were observed in younger populations. For instance, in a 24-year longitudinal study van de Laar et al. [37] showed that individuals with the highest arterial stiffness scores engaged significantly less in VPA during adolescence and young adulthood, whereas no significant effects were observed for light-to-moderate physical activity.

Despite these promising results, insights regarding the potential of VPA to protect against mental health complaints are still limited. In a longitudinal study with middle-aged women, Pavey et al. [31] found that odds ratios for depressive symptoms were similar for VPA compared to moderate-to-vigorous physical activity (MVPA), except at very high levels of physical activity exceeding 2000 MET min wk⁻¹. Similarly, Lindwall et al. [40] observed that adults who regularly engage in LPA or MVPA have comparably reduced odds for anxiety, depression and burnout if compared to inactive individuals. This is in line with the prospective findings of Jonsdottir et al. [41] who found that the risks of depression, burnout, and high stress are significantly lower among individuals who regularly engaged in either LPA or MVPA.

Taken together, these findings support the idea that health benefits of VPA may go beyond those of LPA or MPA, both as physical and mental are concerned. Nevertheless, some methodological limitations warn against an overgeneralization of the existing findings. First, few studies have applied objective measurements to assess levels of physical activity. Second, several studies used arbitrarily set benchmarks to distinguish sufficient versus insufficient levels of VPA without referring to contemporary physical activity recommendations. Third, few studies controlled for LPA or MPA when studying the relationship between VPA and health. Fourth, there is still relatively little research regarding mental health outcomes although mental health problems are on the increase world-wide [42]. Finally, most studies have looked at direct relationships between VPA and mental health, whereas few have considered the potential of VPA as a stress buffer.

Given this background, the following three study questions will be addressed in the present paper:

1. Do young adults who accomplish the ACSM’s vigorous-intensity exercise recommendations differ from peers below these standards with regard to their level of perceived stress, depressive symptoms, perceived pain, and subjective sleep complaints?
2. Do young adults below and above the ACSM’s vigorous-intensity exercise recommendations differ with regard to their objectively assessed sleep patterns?
3. Do young adults below and above the ACSM’s vigorous-intensity exercise recommendations differ with regard to their depressive symptoms, perceived pain, and subjective sleep complaints particularly if they perceive high stress?

Based on previous research with physical health outcomes [32–38], which suggested improved outcomes for individuals engaging in VPA as compared to those engaging in MPA, our hypotheses are that participants who meet vigorous-intensity exercise standards perceive less stress [18], report fewer depressive symptoms [43], less pain [44], fewer subjective sleep complaints [45] and a more favorable objective sleep pattern [28]. Ultimately, we expect that participants who meet vigorous-intensity exercise guidelines cope more successfully with high levels of subjective stress [22,23].

2. Methods

2.1. Participants and procedure

Participants were 42 undergraduate students from the University of Basel, Switzerland (22 women, 20 men; total sample: M age = 21.24 years, SD = 2.20; women: M age = 20.65 years, SD = 1.39; men: M age = 21.77 years, SD = 2.65) who were recruited via word-of-mouth recommendation. These voluntary participants received detailed information about the purpose of the study. Participants were assured confidentiality, and they gave written informed consent before providing their demographic background and subjective assessments of stress, depressive symptoms, pain and subjective sleep complaints. Additionally, they wore an accelerometer device for seven consecutive days. All participants were instructed on how to handle the accelerometer. Twenty-two participants volunteered to take part in a supplementary sleep-EEG assessment. T-tests showed that these students did not differ in any of the study variables from students who did not participate in the sleep-EEG recordings (all p > .05). Sleep-EEG devices were applied via in-home conditions on a Tuesday or Thursday night. Objective physical activity and sleep-EEG recordings were carried out shortly after the participants had completed the psychological questionnaires. All participants received a food voucher (worth 12 Swiss Francs) as incentive. The local ethics committee approved the study protocol and the study was conducted in accordance with the Declaration of Helsinki.

2.2. Measures

2.2.1. Physical activity

Physical activity was assessed with an accelerometer (GT1M, Actigraph, Shalimar, FL, USA) worn around the hip. Seven consecutive days of measurement were included to assess a full weekly period. The sampling epoch was set at 15 sec [46]. Participants were instructed...
not to wear the accelerometer during the night. Time per day spent in MPA (1952–5724 cpm [counts per minute], >3 MET [Metabolic Equivalent of Task]) and VPA (>5724 cpm, >6 MET) was determined based on the raw accelerometer counts and the ActiLife® computer software, with cut-off values derived from Freedson and colleagues [47].

2.2.2. Stress
General perceived stress during the past month was assessed with the widely used Perceived Stress Scale (PSS) [48]. The PSS consists of ten short items measuring the frequency with which respondents found their lives unpredictable, uncontrollable, and overloading (e.g., ‘How often have you felt that you could not control the important things in your life?’). Answers were given on a 5-point Likert scale from 1 (never) to 5 (very often). Items were summed to obtain an overall score. Adequate validity and reliability of this instrument have been established previously [49]. The Cronbach’s alpha in the present study was .86 for the total sample.

2.2.3. Depressive symptoms
The German version of the Beck Depression Inventory (BDI) [50] was used to assess the severity of depressive symptoms. The BDI consists of 21 items including a range of affective, behavioral, cognitive, and somatic symptoms that are indicative of unipolar depression (e.g. ‘I am so unhappy/sad that I can’t stand it’). Each item contained four responses that reflected increasing levels of depressive symptomatology. Possible scores ranged from 0 to 63 with higher scores indicating more depressive symptoms. Adequate validity and reliability of the BDI have been shown previously [51]. The Cronbach’s alpha in the present study was .81 for the total sample.

2.2.4. Perceived pain
The Somatosensory Amplification Questionnaire (SAQ) was used to assess participants’ cognitive-emotional elaboration of pain [52]. The SAQ consists of ten items focusing on the tendency to experience somatic and visceral sensation as unusually intense and disturbing. The questionnaire involves bodily hypervigilance, the predisposition to focus on certain weak and infrequent bodily sensations, and a tendency to appraise them as pathological and symptomatic of disease, rather than normalizing them. Typical items are: “When I bruise myself, it stays noticeable for a long time”; or “I have a low tolerance for pain”. Answers are given on a 5-point Likert scale ranging from 0 (not at all true) to 5 (completely true), with higher mean scores reflecting an increased somatosensory amplification (Cronbach’s alpha in the present sample = .76).

2.2.5. Subjective sleep complaints
The Insomnia Severity Index (ISI) [53] was administered to assess participants’ subjective sleep complaints. The items refer in part to the DSM-IV-TR criteria for insomnia [54], asking participants about difficulty falling asleep, difficulties staying asleep, and early morning awakening. Answers were given on a 5-point rating scale ranging from 0 to 4 (not at all to very much). The higher the sum score, the more the person is believed to suffer from insomnia (Cronbach’s alpha in the present sample = .92).

2.2.6. Objective sleep pattern
Sleep EEG assessments were performed on the last accelerometer day, using a portable EEG-recording device (Fp2-A1; electrooculogram; electromyogram; SOMNOwatchTM, Randersacker, Germany). Previous experience with simple sleep-EEG devices has proved to provide satisfactory data [28]. The advantage of a portable sleep-EEG device is that participants can sleep at home in familiar surroundings. Participants were requested to adhere to their normal evening routines. Sleep polygraphs were visually analyzed by two experienced raters according to the standard procedures [55]. Sleep parameters were analyzed according to the definitions in the standard program described by Lauer et al. [56]. The device provided assessment of total sleep time (TST), sleep onset latency (SOL), sleep efficiency (SE), stages 1—4, light sleep (stages 1 and 2), slow wave sleep (stages 3 and 4), REM-sleep, REM-sleep latency, and number and time of awakenings after sleep onset.

2.3. Statistical analyses
To examine the first study question, a series of one-factorial analyses of covariance (ANCOVAs) was calculated to compare the measurements from the participants who meet or do not meet the ACSM’s vigorous-intensity exercise recommendations. In the present sample, however, all participants accomplished the minimum MPA standards with levels of moderate-intensity exercise ranging from 164 to 775 min per week (M = 350, SD = 114), and levels of moderate-to-vigorous physical activity from 170 to 993 min per week (M = 419, SD = 143). Given this background, we compared students who engaged in vigorous-intensity exercise (≥20 min of VPA at least three times per week) in addition to the ACSM’s MPA recommendations (≥150 of MPA per week) with those who only engaged in MPA. In the ANCOVAs, mental health outcomes were treated as continuous variables. Age, gender (females = 0, males = 1) and MPA were used as covariates. The same statistical procedures were used to examine the second study question using the objective sleep parameters as outcome variables. Finally, to examine the third study question, several two-factorial ANCOVAs were calculated to test the interaction effects between VPA and stress. Due to the low number of students with objective sleep data, only self-reported depressive symptoms, perceived pain and subjective sleep complaints were used as outcome variables in these analyses. To ensure a sufficient number of participants per cell, a median split (cut-off value: ≤21 = low stress [n = 21], ≥22 = high stress [n = 21]) was used to classify participants into two commensurate groups with varying stress levels. Main and interaction effects were tested against the 5% level of significance. Nevertheless, eta square (η²) coefficients were used to evaluate the strength of relationships because they do not depend on the sample size. Following Cohen [57], η² values from .010 to .059 were interpreted as small effects, from .059 to <.138 as medium effects, and from .138 as large effects. Chi²-tests were used to analyze if VPA grouping was related to gender, while an ANOVA tested the association between VPA and age.

3. Results
3.1. Descriptive statistics
Nineteen participants met the ACSM’s standard for VPA and MPA. Twenty-three met the standard for MPA only. Participants’ levels of VPA varied between 0 and 213 min per week (M = 69.0, SD = 57.4). Males (n = 10, 48%) and females (n = 8, 44%) were equally represented in the group meeting the vigorous-intensity exercise standards, Chi²(1,11) = .24, p = .62. Participants who were above versus below the ACSM’s vigorous-intensity exercise standards did not differ with regard to age, F(1,11) = 0.23, p = .64, but – expectedly – had significantly higher VPA scores, F(1,11) = 96.24, p < .001, η² = .71 (above: M = 123 min, SD = 44; below: M = 27 min, SD = 16). The mean score for the PSS was M = 22.8 (SD = 6.0, range = 14—40), skewness = 0.7, kurtosis = 0.3), M = 4.7 for the BDI (SD = 6.3, range = 0—34, skewness = 0.1, kurtosis = -0.7), M = 21.5 for the SAQ (SD = 5.4, range = 12—34, skewness = 0.2, kurtosis = -.5), and M = 6.2 for the ISI (SD = 4.3, range = 0—19, skewness = 0.9, kurtosis = 1.0). Ten percent of the participants reported mild depression (scores from 10 to 18; n = 3) or moderate depression (scores from 20 to 28; n = 1) [50], whereas 29% reported subthreshold insomnia (scores from 8 to 14; n = 10) or moderate-to-severe insomnia (scores from 21 to 28, n = 2) [5].
3.2. Differences in stress, depressive symptoms, perceived pain and sleep complaints

Table 1 shows that participants above the ACSM’s vigorous-intensity exercise recommendations perceive less stress, experience fewer depressive symptoms, report less pain, and suffer from fewer subjective sleep complaints. After controlling for age, gender and MPA, the level of explained variance (10.4-17.7%) points out that the strengths of the effects were of moderate (for depressive symptoms) or strong practical relevance (for perceived stress, pain, and insomnia).

3.3. Differences in objectively assessed sleep pattern

The means and standard deviations for the objective sleep parameters are displayed in Table 2, separately for participants below versus above the ACSM’s vigorous-intensity exercise recommendations. The findings show that besides differences in subjective sleep complaints, the two groups also differ with regard to several objective sleep indicators. Specifically, the following pattern of results was found: First, participants who do meet the ACSM’s vigorous-intensity exercise guidelines sleep around 45 min longer (6 h 55 min) than participants below the recommendations (6 h 11 min). Furthermore, the quality of the extra sleep of participants above the ACSM’s vigorous-intensity exercise standards was higher; they present more stage 4 sleep (99 min versus 75 min) and REM sleep time (89 min versus 64 min). A significant difference also existed for slow wave sleep time (137 min versus 114 min). Moreover, if total sleep time is used as a standard of comparison, the findings indicate that participants above the ACSM’s vigorous-intensity exercise guidelines have lower percentages of light sleep (45.5% versus 53.4%) and higher percentages of REM sleep (21.6% versus 17.2%). The $\eta^2$ values point out that all significant effects were of high practical relevance (explained variance between 21.7% and 33.9%), even after controlling for age, gender and MPA. No significant differences were found for sleep onset latency (SOL), sleep efficiency, stage shifts and number of awakenings after sleep onset.

3.4. VPA as moderator of the relationship between stress, depressive symptoms, perceived pain and subjective sleep complaints

The results pertaining to the third study question are summarized in Table 3. Higher perceived stress was significantly positively associated with more depressive symptoms, increased pain, and more sleep complaints (17.7–29.0% explained variance in Model 2). In line with the univariate ANCOVAs presented above, engaging in VPA was associated with low levels of pain, and decreased insomnia symptoms. With pain as an outcome, a significant interaction occurred between stress and VPA. In support of our hypothesis, Fig. 1 illustrates that VPA was unrelated to pain among participants with low stress levels, whereas those who did not meet recommended VPA levels perceived more pain during high stress than participants who accomplish VPA standards. Although not statistically significant, Figs. 2 and 3 reveal that the results for depressive symptoms and insomnia point into a similar direction, with levels of explained variance in the low (depressive symptoms: 1.4%) and moderate range (insomnia symptoms: 7.2%).

4. Discussion

The key findings of the present study are that among young adults meeting basic moderate-intensity physical activity recommendations, additional vigorous-intensity exercise consistent with the ACSM’s guidelines of three times 20 min per week has additional mental health benefits. Participants above these standards perceived less stress, reported less pain, exhibited fewer sleep complaints, and reported fewer depressive symptoms than their moderate-intensity exercising peers. Furthermore, participants above the ACSM’s vigorous-intensity exercise recommendations had longer total sleep time, less light sleep, and more REM and deep sleep. Finally, the present study shows that young adults above vigorous-intensity exercise standards reported fewer mental health problems than their moderate-intensity exercise counterparts even if they perceived high subjective stress.

With the first study question, we examined whether young adults who accomplish the ACSM’s vigorous-intensity exercise recommendations differ from peers below these standards with regard to their level of perceived stress, depressive symptoms, perceived pain, and subjective sleep complaints. In support of previous research with young people [6,16–21], our hypotheses were predominantly confirmed: young adults above the vigorous-intensity exercise standards reported decreased levels of stress, pain, and fewer subjective sleep complaints. For several reasons, these findings deserve special emphasis: First, most previous studies have looked at the health benefits of active versus inactive lifestyles [28,43]. In contrast, our results show that meeting additional vigorous-intensity exercise recommendations is associated with fewer mental health problems among young adults who already fulfill basic MPA standards, suggesting that intensity, not simply activity, plays a crucial role. This is further supported by the fact that all our participants engaged in a high volume of MPA. Second, to the best of our knowledge, this is the first study that explores the relationship between objectively assessed physical activity and subjective stress [58]. We found that participants engaging in VPA perceived less stress in their lives, and importantly, as discussed below, were better able to cope even in times of high perceived stress. Third, this study contradicts a previous study with young adults showing that the relationship between high rates of self-reported physical activity and good subjective sleep might be merely perceived as such [59]; our use of objective sleep measurements and accelerometer data allowed us to confirm the significant improvements in sleep time and quality for vigorous exercisers. Finally, although few participants reported levels of mild to moderate depression in the present sample (the prevalence of participants suffering from depressive symptoms was lower in the present sample than in the average of college student studies [8]), which might have led to a certain floor effect due to the relatively low variance in the sample, we were able to demonstrate significant differences in depressive symptoms between participants below versus above the ACSM’s vigorous-intensity exercise recommendations. While at this stage we have not sought to explore the reasons for these effects, the broad range of available variables, and our objective measurements of activity and sleep, provides us with a solid basis for consideration of the mechanisms behind our results. In particular, our findings concerning sleep and stress suggest possible causes for the observed
The question that arises now is by what mechanism vigorous exercise promotes healthy and restoring sleep. Similarly, individuals engaging in VPA might be likely to be concerned about their physical performance abilities, and so may make conscious efforts to sleep early, avoid stimulants, and therefore protect themselves from the behaviors that can harm sleep.

Finally, our findings suggest that young adults below and above the ACSM’s vigorous-intensity exercise recommendations differ with regard to their levels of depressive symptoms, perceived pain, and subjective sleep complaints particularly if they perceive high stress. While stress-buffer effects have been documented in previous research [23, 58], this is the first study using accelerometer data, vigorous-intensity exercise standards, and perceived pain and subjective sleep complaints as outcome variables. Prior research showed that pain and sleep are positively correlated among young people [72]. In line with this, our findings pointed toward a mitigating influence of higher VPA levels for both perceived pain and sleep (although the findings were only significant for pain). The interaction terms explained 7.2% (insomnia) and 15.5 percent of variance (pain). This is remarkable as the stress-buffer effects detected in previous studies were of relatively small magnitude (1–4% of explained variance) [58]. Moreover, while previous studies have shown that regular physical activity can protect against stress-related depressive symptoms, such a moderation effect was statistically not supported [18]. However, as shown in Fig. 3, a trend in this expected direction appeared, which is noteworthy given the notorious difficulty of detecting interaction effects in field studies [73].

We therefore have some evidence for a stress-buffering effect of VPA, with on one hand low perceived stress among vigorous exercisers, and on the other hand fewer psychological complaints despite high perceived stress. This may be a causal factor in the better mental health outcomes of those engaging in VPA. As noted in the introduction, high stress can disrupt sleep, cause depression and affect pain perception, hence an improved ability to cope with or avoid stress may have positive effects on these variables. Further research into the interplay between stress and the intensity of physical activity is required, in order to explore the degree to which this mechanism acts, and whether it is physiological, or results in improved mental toughness and coping strategies for difficult situations.

Although the present study provides strong support for the mental health benefits associated with meeting vigorous-intensity exercise standards, the findings should be interpreted in light of the study’s limitations: The sample size (particularly for the objective sleep data) was small.

**Table 2** Differences in stress, depressive symptoms, pain and insomnia between students below versus above vigorous-intensity exercise recommendations.

<table>
<thead>
<tr>
<th></th>
<th>Below recommendations (n = 10)</th>
<th>Above recommendations (n = 12)</th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>TST (min)</td>
<td>371.2</td>
<td>34.9</td>
<td>414.6</td>
<td>35.9</td>
</tr>
<tr>
<td>SOL (min)</td>
<td>21.7</td>
<td>11.4</td>
<td>21.7</td>
<td>11.8</td>
</tr>
<tr>
<td>Sleep efficiency (%)</td>
<td>93.2</td>
<td>3.0</td>
<td>94.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Stage shifts (index)</td>
<td>16.3</td>
<td>3.1</td>
<td>16.6</td>
<td>4.1</td>
</tr>
<tr>
<td>Awakenings after sleep onset</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 1 (min)</td>
<td>15.8</td>
<td>11.3</td>
<td>12.8</td>
<td>8.2</td>
</tr>
<tr>
<td>Stage 1 ( % of TST)</td>
<td>4.3</td>
<td>3.1</td>
<td>3.7</td>
<td>2.3</td>
</tr>
<tr>
<td>Stage 2 (min)</td>
<td>183.1</td>
<td>34.3</td>
<td>176.1</td>
<td>35.6</td>
</tr>
<tr>
<td>Stage 2 (% of TST)</td>
<td>49.1</td>
<td>6.2</td>
<td>42.4</td>
<td>7.6</td>
</tr>
<tr>
<td>Stage 3 (min)</td>
<td>33.1</td>
<td>12.0</td>
<td>37.7</td>
<td>17.9</td>
</tr>
<tr>
<td>Stage 3 (% of TST)</td>
<td>8.9</td>
<td>2.8</td>
<td>8.9</td>
<td>3.6</td>
</tr>
<tr>
<td>Stage 4 (min)</td>
<td>75.1</td>
<td>20.6</td>
<td>98.7</td>
<td>29.8</td>
</tr>
<tr>
<td>Stage 4 (% of TST)</td>
<td>20.5</td>
<td>6.3</td>
<td>24.0</td>
<td>7.5</td>
</tr>
<tr>
<td>Light sleep (min)</td>
<td>198.9</td>
<td>35.9</td>
<td>192.2</td>
<td>42.6</td>
</tr>
<tr>
<td>Light sleep (% of TST)</td>
<td>53.4</td>
<td>7.0</td>
<td>45.5</td>
<td>8.7</td>
</tr>
<tr>
<td>Slow wave sleep (%)</td>
<td>114.2</td>
<td>19.9</td>
<td>137.2</td>
<td>36.9</td>
</tr>
<tr>
<td>Sleep stage (min)</td>
<td>29.4</td>
<td>5.3</td>
<td>32.9</td>
<td>8.7</td>
</tr>
<tr>
<td>REM sleep (min)</td>
<td>64.1</td>
<td>16.4</td>
<td>89.3</td>
<td>15.1</td>
</tr>
<tr>
<td>REM sleep (% of TST)</td>
<td>17.2</td>
<td>4.0</td>
<td>21.6</td>
<td>3.5</td>
</tr>
</tbody>
</table>

small leading to a number of participants per cell below recommended levels (n = 20) when main and interaction effects were calculated [74]. Accordingly, gender could only be used as a covariate, and not as an additional fixed factor. The cross-sectional data preclude conclusions about cause and effect, and the sleep assessment was performed with a relatively simple device and only on a single weekday night. Finally, the analyses are based on a convenience sample of university students. Thus, cautious interpretations are warranted regarding the generalizability of the data until the results can be corroborated with larger and broader samples.

5. Conclusions

This study provides evidence that meeting the vigorous-intensity exercise standards of the ACSM is associated with improved mental health and more successful coping among young people, even compared to those who are meeting or exceeding the requirements for MPA. This is remarkable as the ACSM physical activity recommendations were originally conceived with an emphasis on developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness. However, our data suggest that VPA is an important factor in stress management, pain perception, and subjective and objectively assessed sleep quality, as well as having possible implications for depression.

![Fig. 1. Differences between participants below versus above vigorous-intensity exercise recommendations on the Somatosensory Amplification Questionnaire (SAQ), if experiencing low versus high stress.](image1)

![Fig. 2. Differences between participants below versus above vigorous-intensity exercise recommendations on the Insomnia Severity Index (ISI), if experiencing low versus high stress.](image2)
Thus, VPA emerges as not only an essential part of cardiovascular health, but also a protective factor against a variety of common and troubling mental health complaints. Furthermore, in comparing individuals practicing VPA with those who already practice MPA, rather than a totally inactive population we were able to show that vigorous intensity itself appears to be the key factor, and MPA does not have such a significant protective effect. Further studies must therefore explore the mechanism behind VPA, in order to further understand its role in mental health, in order that preventive health guidelines can be adapted accordingly.

Fig. 3. Differences Between Participants Below versus Above Vigorous-Intensity Exercise Recommendations on the Beck Depression Inventory (BDI), if Experiencing Low Versus High Stress.

References


