# The relationship between physical activity, sleep, and coping skills among adolescent vocational students, and the effects of a physical education-based coping training

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# Summary


## Background and aims

Adolescence is defined as a vulnerable period characterized by several physiological and psychosocial changes that affect health and behavior. Although most adolescents successfully manage the transition between childhood and adulthood, the speed and magnitude of these changes exceed the coping abilities of a significant amount of young people. Furthermore, due to the important role of sleep within the stress−health relationship, research draws attention to the maturational sleep changes in adolescence. One study showed that impaired sleep increased the risk for poor psychological well-being. In contrast, sleep disturbances may also result from higher stress levels. However, research on the relationship between stress, coping and sleep among vocational students is scarce. This is surprising, given that 74% of all secondary school diplomas in Switzerland are granted to students with vocational education and training (VET). Therefore, the aim was to implement a physical education-based coping training (EPHECT) among two vocational schools and to evaluate effects on perceived stress, coping and sleep.

Thus, the aims of this thesis were to summarize the state of the art of physical activity and sleep among adolescents, to assess the prevalence and correlates of sleep complaints, physical activity and psychological well-being among adolescent vocational students and to find out whether a physical education-based coping training can increase psychological functioning (short and medium-term effects).

## Methods

A quasi-experimental approach was adopted for the pilot (EPHECT I) and the follow-up study (EPHECT II). Possible intervention effects on stress, coping and sleep between pre- and post-intervention (EPHECT I and EPHECT II) and 6-months follow-up (EPHECT II) were assessed.

EPHECT I: Two comparable vocational schools participated in the study, and one of them received the intervention program, while the other school maintained regular physical education (PE) classes (N = 1244 students: M = 17.98 yrs.; SD = 1.36; 531 females). All participants completed a battery of self-report psychological questionnaires (assessing perceived stress, coping skills, sleep quality, and physical activity). In addition, physical activity and sleep were objectively measured (actigraphy, EEG) within a subsample (n = 56).

EPHECT II: In the follow-up study (N = 131), 64 students from four classes received EPHECT during physical education (PE) class, while the CG (n = 67) had conventional PE class. The psychological questionnaires were administered again to all students pre- and post-intervention.

**Results**

The meta-analysis showed that differences in assessment methods and poor correlation between subjective and objective measurement make it difficult to compare data from different studies. Only one study compared subjective and objective assessments for both sleep and exercise; therefore, more research is need to close gaps in knowledge, such as regarding the aims of the meta-analysis, which was not reached completely, namely whether the assessment tool influences the results. In general, it was found that adolescents who exercise more report better sleep. However, physical activity (PA) and sleep onset latency (SOL) are frequently overestimated, while total sleep time (TST) is frequently underestimated. Additionally, it was found that females tend to be less active than males.

EPHECT I confirmed the findings that TST is frequently under-estimated and physical activity and SOL are over-estimated and that females are less active than males. The study also showed that students of the intervention group with initial lower life satisfaction showed a reduction in maladaptive coping strategies. However, the implementation rate did not moderate the findings. As the study had problems with teacher compliance and subsequent student motivation, an improved version of EPHECT was therefore designed and implemented in a few classes only (EPHECT II). EPHECT II showed much better teacher compliance and findings revealed improvements of adaptive coping skills in IG students. The six-month follow-up showed decreased levels of perceived stress in IG students compared to CG and to baseline, an effect that was not detectable at the end of the intervention. A path analysis suggested an indirect effect on stress perception at follow-up via improved adaptive coping skills.

**Conclusion**

The presented studies within this thesis provide an important basis toward future investigations targeting the relationship between physical activity and sleep. A physical education-based training program with the goal of fostering adaptive coping skills and reducing maladaptive coping strategies and stress perception was developed, which can be implemented in a time-efficient manner into the existing PE-syllabus of vocational schools. This program has the potential to reduce future stress in adolescents who are in a vulnerable phase of transition and enable them to become a valuable part of their communities and society in general.

# Common abbreviations

| | |
|---|---|
| BMI | Body Mass Index |
| ACSM | American College of Sports Medicine |
| CDC | Centers for Disease Control and Prevention |
| CI | Confidence Interval |
| DLW | Doubly Labeled Water |
| ECG | Electrocardiography |
| EEG | Electroencephalography |
| EMG | Electromyography |
| EOG | Electrooculography |
| EPHECT | Effects of a Physical Education-based Coping Training |
| $I^2$ | Statistical Index of Heterogeneity |
| IPAQ | International Physical Activity Questionnaire |
| ISI | Insomnia Severity Index |
| Mesh | Medical Subject Headings |
| MVPA | Moderate to Vigorous Physical Activity |
| PA | Physical Activity |
| PRISMA | Guidelines for preferred reported items for systematic reviews and meta-analysis |
| PSG | Polysomnography |
| SOL | Sleep onset latency |
| TST | Total sleep time |
| VET | Vocational education and training |
| VPA | Vigorous physical activity |
| WASO | Wake after sleep onset |

# CHAPTER 1

## Introduction

## INTRODUCTION

> *People say, 'I'm going to sleep now,' as if it were nothing. But it's really a bizarre activity. 'For the next several hours, while the sun is gone, I'm going to become unconscious, temporarily losing command over everything I know and understand. When the sun returns, I will resume my life.*
>
> George Carlin

Although the exact functions of sleep are not yet completely understood, it is an important physiological process, and poor sleep can cause severe physical and psychological problems. Sleep deprivation, a condition that can be brought on by chronic or acute lack of sleep or poor sleep quality, can lead to under-performance in daily functioning, cause accidents due to limited ability to pay attention, and cause long-term health problems [1].

In adolescence, profound changes of physiologic functions can lead to changes in sleeping patterns, disturbed sleep and ultimately sleep deprivation [2,3]. Sleep deprivation can cause academic failure as well as depression [4] in adolescent students. In contrast, increased amounts of physical activity benefit several medical and psychological conditions including cardiovascular disease, obesity, type II diabetes, cancer, arthritis, depression, and sleep disturbances [5–9]. Thus, physical activity has been implemented as an important tool for preventing and treating insomnia and stress management [10].

While the term “physical activity” is often confounded with terms like “exercise” and “physical fitness”, all three are defined separately. Physical activity (PA) encompasses any form of body movement produced by skeletal muscles, leading to energy expenditure above basal level [11]. Physical activity includes all daily activities, including domestic (e.g., gardening), occupational (e.g., farming), and leisure-time (e.g., running) as well as active transportation (e.g., walking and cycling). Exercise, a subcategory of PA, is planned, structured and repetitive body movements with an underlying goal or subgoal. In contrast, physical fitness is a physiological attribute that can be health- or skill-related and is influenced by variables such as sex, age, genotype and certain behavioral determinants (e.g. exercise history, smoking, motivation) [12,13]. Specific objective tests can measure the degree of an individual’s physical fitness (e.g., VO2 max indicates cardiovascular fitness and aerobic endurance) [11].

### Changes in sleep as a function of adolescent development

Adolescence is the period of transition from childhood to adulthood and is characterized by rapid changes in physiological, psychiatric, socio-cultural, and psychological states that affect health and behavior [14,15]. These changes impose varying amounts of stress, which could negatively affect the quality and quantity of sleep that adolescents experience [11,16–18]. Contrarily, insomnia and poor sleeping patterns compound negative stress responses and diminish healthy coping strategies. Thus, poor management of sleep problems, or poor sleep hygiene, can result in unfavorable effects on adolescent well-being, impacting academic performance, psychological health, and behavior [11,16–18]. The transition to college or professional life rarely solves problems of poor sleep quality and quantity rather, it enhances them [19]. In particular, vocational students, who prepare for trade-based careers, are confronted with new responsibilities that stem from academic challenges and job requirements alike. This can create more stress and lead to additional sleep disruption.

Neurobiological mechanisms can also have an impact on the regulation of adolescents' sleep. Both circadian and homeostatic components of sleep alter and impact the sleep–wake cycle, as well as the duration, timing, and architecture of sleep [3,20]. The most striking change in sleep patterns during adolescence is the decrease in slow wave sleep (SWS) [3,21,22]. Specifically, biological sleep patterns tend to shift over the course of adolescence towards later sleep and wake times. This pattern also moves sleep onset later into the night, not only decreasing the ability to achieve sufficient sleep on school nights, but also increasing the tendency to wake later on weekends [16,23]. The desire for teenagers to become independent from their parents reinforces this pattern, as they determine their own bedtime.

In summary, sleep is a crucial factor that impacts not only the academic, but also the psychological and behavioral performance of adolescents [11,16–18]. Moreover, adolescence is a vulnerable period in life that has a high incidence of psychiatric illnesses, which may be induced or exacerbated by sleep deprivation [16]. The national sleep foundation reports that in order to achieve optimal performance, adolescents still require between eight to ten hours of sleep per night; however, the majority sleep less [3,11,16]. Major causes of insufficient sleep in adolescents can be intrinsic in nature, such as physical, psychological, and social changes or extrinsic changes, such as different school start times and increased personal responsibility [16].

**Prevalence of sleep disturbances among adolescents and young adults**

The transition to college or professional life may be particularly stressful, and sleep patterns can be one of the first daily habits to change for many college entrants [4,18,19,24]. This can lead to a high prevalence of sleep deprivation in adolescents and young adults. Lund et al. found that nearly 60% of students ages 17–24 (N = 1,125) suffered from poor sleep quality [19], and the issues of insufficient and disrupted sleep in mid- to late-adolescence continue into early adulthood. Other studies found similar results with 50% of the students examined reporting daytime sleepiness, while only 30% obtain sufficient sleep [4]. Therefore, the management of sleep hygiene in adolescents involves, among other things, increasing total sleep times and adjusting other environmental factors that impact sleep, such as physical activity and caffeine intake.

## Effects of physical activity on sleep

> *I think the best way to get a good night sleep is to work hard throughout the day. If you work hard and, of course, work out.*
>
> William H. McRaven

Anecdotal evidence, such as parents claiming that kids who play hard will sleep well in the coming night, suggests that physical activity and sleep are interrelated. The notion that physical activity promotes better sleep is also quite common in research and might be due to hypotheses about the benefits of sleep such as restoration of energy reserves [25], tissue regeneration [26], and regulation of body temperature [27–29]. However, this belief has been the subject of significant controversy in research over the past few decades. While epidemiologic studies show a clear correlation between physical activity and improved sleep quality [30,31], experimental data have been less conclusive. Since 1966, research had been undertaken to investigate correlations between physical activity and sleep. In a study, Baekeland and Lasky found positive effects of exercise on sleep patterns in college athletes [24]. In the 1970s, Zloty and co-workers were able to show positive effects of long-distance running on sleep quality [32]. In another study performed approximately the same time, Adamson et al. showed increases in serum levels of growth hormone during sleep after exercising [33]. Later studies confirmed these data [27,34–36]. However, several studies failed to find a significant correlation between exercising and improvement of sleep quality or between better performance and control treatments such as stretching and social interactions [37–41].

It is possible that these discrepancies in the results are due to poorly designed studies and differences in study populations in terms of the age, gender, and fitness level of participants. Another discrepancy is between the types of exercise interventions, which can differ based on intensity, duration, whether it is predominantly aerobic or anaerobic, and a number of other factors [27]. Physical activity stimulates positive impacts on sleep quality and general mental health, making it an attractive alternative to more aggressive treatment such as sleeping pills, which can be habit-forming and come with a number of other possible adverse effects [5,7,8,10,19,36,42,43]. However, the exact effects of physical activity on sleep in adolescents in a controlled setting are still poorly understood. Thus, research in this area is needed to understand the underlying mechanisms and the dose-response relationship which can improve the general and mental health and academic performance of adolescents. Conducting such research implies thoughtful consideration in that the accurate measurement of physical activity and sleep among adolescents is fraught with additional challenges. Chapter 4 of this thesis will therefore analyze and discuss the current methodological approaches to assess this relationship. It can, however, be noted that each measurement method imposes an unavoidable trade-off between feasibility and validity, while new technological developments continually shift this balance.

*The assessment of sleep among adolescents*

Sleep assessments can be conducted using self-reported measures such as standardized or researcher-developed questionnaires and sleep diaries [11,44,45]. Actigraphy, polysomnography (PSG), and portable electroencephalogram (sleep–EEG), on the other hand are objective measures of sleep quality and sleeping patterns [11,46,47].

The cost-effectiveness of questionnaires and their unique ability to assess subjective sleep quality makes them one of the most widely used sleep assessment tools. However, findings based on self-report questionnaires are often difficult to compare because of the extreme diversity of the measures used. Additionally, accuracy of the self-reported data has been questioned due to adolescents reporting with a socially desirable bias or the most memorable or recent sleep experience [48]. The use of standardized, validated, and well-established questionnaires such as the Pittsburgh Sleep Quality Index (PSQI), Epworth Sleepiness Scale (ESS), or the Insomnia Severity Index (ISI) can mitigate problems with comparability of results. Furthermore, there are some validated questionnaires especially designed for children and adolescents with sleep problems. The PSQ is a 67-item instrument that has been validated in a wider age range of 4 to 18 years [49]. It covers a wide range of sleep problems in children and has a sleepiness subscale and a sleep-related breathing disorder subscale. The PSQ is easy to administer, making it the only non-PSG tool found to be useful in identifying obstructive sleep apnea. The Children's Sleep Habits Questionnaire (CHSQ) [50] has been used in clinical research and is applicable to screening as well. The CHSQ is a 35-item, 3-page questionnaire validated for 4 to 10-year-old children, but often used in children from 2 to 18 years old. In contrast, Spruyt and Gozal [51] provide information on the theoretical and pragmatic processes required for instrument design and development, i.e., how any questionnaire, inventory, log, or diary should be created and evaluated. Moreover, a recent validation study demonstrated that question wording can affect reported sleep duration in complicated ways [52]. This study examined two different question formats (one general question versus two questions asking separately about weekday and weekend sleep duration) with 1,040 adults (aged 18 and older). Thus, such a survey may evoke difficulties, as adolescents must give a single-value estimate to a phenomenon with much greater variability. On the other hand, weekend nights may better reflect adolescents' sleep patterns, as they contain more information [53]. Above all, sample selection considerations such as high school students vs. college students, age, income, and ethnicity further confound the variables between epidemiological studies [54].

Sleep diaries, also called sleep logs, are another instrument to collect subjective sleep pattern information that can provide a multitude of data among others on bed and waking times, times to fall asleep, changes between weekday and weekend sleeping patterns, daytime sleepiness, and subjective sleep quality. Similar to questionnaires, the accuracy of responses and compliance, however, can pose a significant challenge when asking adolescents to complete sleep diaries [45]. Nevertheless, sleep logs that record the previous night's sleep patterns for a period of one to two weeks are considered more accurate than questionnaires that require the participant to recall sleep patterns over a longer period [48]. A positive correlation between data from sleep logs and objective sleep measures, such as actigraphy and PSG recordings, has been demonstrated [48,55–57].

While sleep-EEG and PSG can provide more reliable and valid assessments of sleep patterns, both are relatively invasive, disturb sleep patterns, and require expensive equipment [11,47]. Since wrist actigraphy has the potential of overcoming these disadvantages, it has become increasingly popular as a method of acquiring objective data on sleep duration, sleep efficiency, and sleep timing over the course of the past decade [58]. These wristwatch-size devices can unobtrusively collect objective data on sleep patterns and activity levels continuously for 1–2 weeks in the usual environment of the adolescent. These devices are largely resistant against collecting subjective or inaccurate data, minimize compliance issues, and, unlike invasive devices, eliminate sleep disturbances [11,46]. Results for total sleep time measured with this method have been validated against PSG in several studies [58,59]. Overall, adolescents have responded well to the use of wrist actigraphy to measure sleep patterns [48,58,60,61].

The invasiveness of PSG can cause a "first night effect," or a disturbance of the sleep pattern in the first night due to the cumbersomeness of the device. Nevertheless, the PSG provides data on multiple parameters, maintaining it as the "gold standard" device in sleep pattern measurement and sleep diagnosis [11]. A PSG usually not only monitors brain function in the form of an EEG and eye movements (Electrooculography = EOG), but also records an electrocardiogram (ECG) and electromyogram (EMG) to evaluate heart rhythm and muscle activity. The very complex data set requires highly-trained personnel to analyze. A less complicated and less expensive alternative that has emerged in recent years is the portable sleep EEG device (Figure 1.1) that can be used in the home of the study subject. These portable devices record sleep data using one to three channels and have been used in several studies with adolescents in the recent past [43,47,62–64]. PSG data as well as actigraphy seem to show a certain robustness in respect to sleep efficiency for individual subjects despite night-to-night variability, even over an extended time frame of 12 months [65–68].

**Figure 1.1. Portable EEG-recording device**
Fp2-A1; electrooculogram; electromyogram; SOMNOwatch™, Randersacker, Germany. Used in EPHECT I, described in Chapter 5.

The cost of these portable devices, measurement methods, and their time-consuming application make their use challenging in large-scale studies. Data should also always be collected for several nights with a specific individual to collect a reliable average sleep pattern, as individual night patterns can be affected by daytime activity, sleep in the previous night, and other factors such as medications, caffeine, and alcohol usage. Finally, an important aspect, but often receiving less attention when studying female subjects, is controlling for the menstrual cycle phase and its impact on sleep.

*The assessment of physical activity among adolescents*

The assessment of physical activity shows certain similarities to that of the assessment of sleep, using both subjective and objective measurement tools. Self-report questionnaires and physical activity logs are common instruments for subjective assessment of PA, providing data to deduce energy expenditure and compliance, whereby recommending healthy amounts of PA. This practice is accepted by international recommendations such as those of the American College of Sports Medicine (ACSM) or the Centers for Disease Control and Prevention (CDC) [69–72]. Several validated questionnaires are available, e.g., the International Physical Activity Questionnaire (IPAQ) (http://www.ipaq.ki.se/ipaq.htm), which is well-established and widely used. While the IPAQ was originally created to assess physical activity in adults at ages between 15 and 69 years, it has been used widely across various populations. Biddle et al. [73] identified three instruments as most suitable for use in epidemiological studies of adolescents: PAQ-A [74], YRBS [75], Teen Health Survey (itself a shortened 2-item modification of the YRBS) [76]. In turn, SHAPES [77] and IPAQ-A [71] assess physical activity elaborately, and are therefore recommended for use in experimental studies [73]. However, similar to epidemiologic data on sleep, a large amount of epidemiologic data stems from limited questions within a epidemiologic questionnaire designed to measure a large variety of features such as "*Was physical training performed at least once per week*?", "*Do you undertake any physical sporting activity after school*?" or "*Frequency of exercise during one week*" [78–80].

Subjective data always runs the risk of inaccuracies due to over-reporting of physical activity by the participants or inaccuracies in recalling the actual events in the past [62]. Objective measures can avoid these problems. Unfortunately, when analyzing adolescent data, the use of adult-based classifications of moderate and vigorous physical activity can lead to an over-estimation itself of physical activity in adolescents [81,82]. Efforts are currently being made to develop a compendium of energy expenditure for youth [83]. Objective assessment, in turn, such as motion sensors, pedometers and accelerometers with similar mechanisms as actigraphy for sleep assessment, direct observation, calorimetry, and physiological markers such as heart rate as well as combinations of these monitors physical activity [84–86] can reduce self-report bias, but there are still variations between the accuracy of these tools. These tools can monitor the intensity, frequency, duration, and total amount of physical activity as well as the type of activities (e.g., walking, jogging running) and differentiate between different sitting and standing [87]. In adolescents, however, a pedometer displaying the number of steps can result in a 3% higher step count during the first day of measurement than subsequent days [72].

Energy expenditure is frequently measured by using doubly labeled water. With this method, a study subject is given water in which both hydrogen and oxygen is partially replaced by the heavy, non-radioactive isotopes deuterium ($H^2$) and $O^{18}$. Sugar metabolized in the body results in metabolite $CO_2$ (doubly labeled water), which can be labeled so that the ratio between excreted $H^2$ and $O^{18}$ provides an accurate objective measure of how much $O^{18}$ was exhaled as $CO_2$ from which energy expenditure can be accurately calculated [58,85,87]. Despite its high cost, the doubly labeled water method of assessment of energy expenditure remains the “gold standard” [58].

**Figure 1.2**. **Wrist-accelerometry**
In the EPHECT I-Study, an accelerometer from SOMNOwatch™, Randersacker, Germany) was applied to measure PA and sleep objectively.

Accelerometry is more easily accessible to large samples at a much lower cost. It has emerged as the most frequently used objective measure of physical activity in recent years [88], providing accurate data on step-based PA. However, expenditure from exercises such as cycling and weight lifting are captured inaccurately and accelerometers cannot be used in contact sports and swimming. Therefore, a physical activity log is advised to adjunct accelerometer data. In adolescent studies, compliance is notoriously a problem and wearing accelerometers (Figure 1.2) can be awkward [89] and impose upon individual style and fashion [72]. Nevertheless, the fact that an accelerometer is capable of assessing both sleep and physical activity makes it an attractive device for large studies [58]. An aspect that should be considered when assessing adolescents is that these study subjects have higher day-to-day variability than children with regard to moderate to vigorous physical activity [90], and protocol compliance tends to decrease over the study trial. Therefore, it is suggested to measure at least for four full days (not necessarily consecutive), including one weekend day [72].

Similar to sleep studies, the comparability of physical activity data across studies is also limited. A large variety of different variables were measured in different studies that correlate moderately. However, comparisons are cumbersome without transformation of data, (i.e. number of steps taken compared to hours of physical activity during a week, fitness as measured by physiologic parameters, energy expenditure, intensity of exercise, etc.) Lastly, when assessing the relationship between physical activity and sleep, physical activity setting (e.g., indoors or outdoors) plays an important role because chronic exposure to bright light can enhance sleep [72,91].

**Stress and its relation to physical activity and sleep**

Stress typically describes a negative concept that can have an impact on one's mental and physical well-being. It is controversial as to what exactly defines stress and whether or not stress is a cause, an effect, or an interchange of the two. Here, the definition of stress refers to the cognitive–transactional stress model proposed by Lazarus and Folkman, which defines stress as a transaction between the person and the environment [92]. Thus, stress occurs if there is an imbalance between internal or external demands and perceived resources available to cope with stress.

Within industrialized countries, many people experience stress, with children and adolescents reporting high amounts of psychological stress [93]. About 450 million people are affected by psychological, neurological, or other behavioral problems worldwide. According to the World Health Organization (WHO), stress is one of the primary causes for the global burden of disease, entailing heavy burdens on both the national health system and financially in the private economy [94]. For example, in Switzerland, stress-associated illnesses cost 4.2 billion Swiss Francs a year, compared to 20 billion Euro in Germany and 300 billion US Dollars in the United States [94–96]. Research indicate that negative impacts of stress and stress-associated illnesses, indeed, generate high costs for the national health systems in western societies. Moreover, a national study with Swiss adolescents showed that improved skills in dealing with negative emotions, stressful situations, and sleeping problems are among the most frequently requested health-related skills by young people [97]. Adolescence is a period of profound changes and most adolescents successfully transition to adulthood, however, the speed and magnitude of these changes exceed the coping abilities of a significant amount of young people [98,99]. An estimated 22% of adolescents in the U.S. experience mental health problems [100]. Findings of a recent study on Swiss vocational students corroborates this finding, as one-third of this population indicate mild school- and job-related burnout symptoms, whereas 16% show strong, and 7% clinically relevant symptoms [101]. It can be projected that other industrialized nations have similar prevalence of mental health issues among adolescents and young adults. Developing effective strategies to foster stress resilience and psychosocial well-being is therefore a crucial point from a public health perspective and requires knowledge about the basic relationship between stress and health.

It has been accepted for decades that stress negatively impacts sleep [31,102–106]. Conversely, sleep can affect physiological mechanisms to enable coping with stress [104], whereby the interrelation of sleep disturbances and stress causes a vicious cycle in periods of increased stress. Research shows that a lack of adequate coping strategies among young professionals may cause, sustain, and exacerbate sleep disturbances [107–109], which in turn, increase stress [110]. However, sleep disturbances may also result from high stress levels [111]. Assessing sleep logs and participant diaries have demonstrated that daily stress is associated with poorer sleep quality [112,113]. Prospective epidemiological studies suggest that impaired sleep increases risk of depressive disorders [114,115] and may facilitate the development of somatic complaints, poor academic achievement, and poor psychological well-being [16]. Adolescents and young adults seem to be affected by similar factors in this relationship between stress and sleep quality among older adults [106,116,117]. Thus, it appears that there is a complicated interrelation of stress and physical activity with stress being alleviated by physical activity on one hand, and on the other hand, a stressful life limiting time and energy for physical activity [5,43,96,99,118]. Additionally, physical activity levels gradually decrease during adolescence [119–121]. Vocational students, in particular, report lower levels of physical activity than peers attending regular high school [122,123]. However, the relationship between physical activity and sleep among vocational students has not been extensively researched until now. The fact that 74% of all secondary school diplomas in Switzerland are granted to students with vocational education and training (VET) underlines the importance of this research [124].

*It`s not stress that kills us, it is our reaction to it.*

Hans Selye

**Stress management**

Mental health problems among adolescents impose high social and economic burdens as they often manifest into disabling conditions later in life. As emphasized by cognitive–transactional stress models [92,125], stressful life circumstances constitute a risk of impinging upon mental and physical health. Several appraisal processes and the availability of skills and resources to cope with stress can, however create an impact on the stress–coping process. Therefore, embracing a broad and balanced repertoire of adaptive or constructive coping skills is key to fostering adolescent resilience, namely the ability to recover from or easily adjust to misfortune or change [126].

To cope with the effects of stress, two of the most prominent buffers are social support and physical activity [5,8,43,47,92,98,99,118,127,128]. According to a recent literature review, physical activity affects sleep and improves the health and well-being of the adolescent and young adult population [10]. As mentioned previously, it is therefore of utmost importance to examine the interplay of sleep, PA, and stress. A gap in the literature exists regarding the effects and the interplay of stress, PA, and sleep, particularly among adolescents and young adults. Thus, preventive interventions should seek to foster such protective factors that reduce the likelihood of negative outcomes or increase participants' resilience and related resources. Having an appropriate coping repertoire may help to reduce the long-term risk for stress-related diseases [126].

Young people are often uninterested in health prevention programs [129]. In fact, results of a study on health promotion among adolescents revealed that from fifth to tenth grade, only one-third were interested in participating in stress management training [130]. Fear of stigmatization [129,131], or having a good perception of one's health [132,133] might be reasons for low interest in health prevention programs. Despite the fact that students with higher stress levels show a greater interest in health prevention [130], the problem remains that adolescents are a difficult population to reach [134].

This thesis will therefore focus on the relationship between PA, sleep, stress and coping skills among adolescents and particularly in vocational students, who must balance job and academic requirements. Moreover, this thesis deals with the question of whether a physical education-based coping training could impact the relationship between PA, sleep, stress, and coping.

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# CHAPTER 2

## PhD research objectives

## PHD RESEARCH OBJECTIVES

Based on the gaps of knowledge on stress and coping, sleep, and physical activity among vocational students, the aims of this thesis were as follows:

**Background of aim 1:** Physical activity (PA) is widely viewed as an alternative to pharmacological approaches of improving sleep quality without the side effects. Assessment of both physical activity and sleep has been met with significant challenges in adolescent and young adult populations. Comparing data from different studies can pose challenges related to data collection methodology, reporting, and population variance, to name a few.

**Aim 1:** While there are several reviews published that attempt to analyze data on the relationship and confounds of physical activity and sleep in adolescents, a systematic review that analyzes differences in measurement methods and compares data across these confounding features was not available. Consequently, aim 1 of this study was threefold; (a) to perform a meta-analysis to assess the influence of the various approaches on effect size and (b) to investigate the influence of physical activity on sleep in a large sample of adolescents across multiple studies and (c) to examine which tools, i.e., objective or subjective measures were used for data collection.

**Background of study aim 2:** As described in our systematic review and meta-analysis, more studies are needed, which apply both subjective and objective measures for the assessment of physical activity and sleep within the same population.

**Aim 2:** Aim 2 was to (a) assess physical activity and sleep both subjectively and objectively, (b) to examine correlations between the two, and (c) to assess whether objective or subjective physical activity is positively correlated with sleep (measured objectively or subjectively).

**Background of study aim 3:** Managing the transition from childhood to adulthood can be perplexing, entailing physiological, psychological, and sociological changes. The majority of adolescents can successfully transition without cause for concern, conversely a portion of young adults exude poor coping capabilities and become overwhelmed during this time period. Vocational students face even more challenges than typical high school or college students, because vocational training requires a balance between academic and job-related responsibilities. Mounting evidence suggest that the transition to adulthood is categorized by a period of increased susceptibility to psychiatric problems and, as such, teaching adequate coping strategies should become a health priority. The negative impact of stress on both physical and mental health has led to the inception of school-based resilience promotion programs by various federal governments. For instance, the new physical education (PE) curriculum of vocational students in Switzerland aims to teach stress management to combat the growing incidence of stress-related diseases among young professionals at the workplace.

**Aim 3:** This aim was to develop and implement a PE-based coping training (EPHECT) for vocational students, through practical, movement-based exercises (a), and to evaluate possible intervention effects on coping skills and stress perception (b). This study also aims to determine whether EPHECT is able to reach the estimated 10–20% of adolescents who would benefit from mental health services (c). Thus, the study includes a responder analysis of students with low versus elevated life satisfaction. Finally, implementation rate was considered as a moderating factor.

**Background of study aim 4:** Evaluating the results of EPHECT I showed that there was significant scope for improvement regarding the implementation of the coping training program. One of the biggest problems of EPHECT I was teacher compliance. The training program contained 8 modules with a total of 12 individual lessons, and many teachers were not very motivated to participate. Additionally, the use of the workbook was not clearly explained to all students.

**Aim 4:** This aim was, therefore, to improve the implementation of EPHECT among vocational students (a). The implementation differed in that an improved workshop for PE teachers was provided, with a special focus on the reflection period. An additional part of this aim is to evaluate stress levels, coping skills, and sleep quality in students before and immediately after implementation of the coping training program (b).

**Background of study aim 5:** There is a paucity of data on the long-term effects of coping training on coping skills and perceived stress levels, which lead to the formulation of the last aim of this thesis.

**Aim 5:** Aim 5 was to implement the improved version of EPHECT and evaluate stress levels and coping skills in vocational students, six months after the students received coping training.

# CHAPTER 3

## EPHECT – Effects of a Physical Education-based Coping Training

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This thesis not only focuses on the impact of regular physical activity on sleep, but it also evaluates the effects of the EPHECT study, a physical education-based coping training for Swiss vocational students on perceived stress, coping, and sleep. To better understand the EPHECT study, a short description of the Swiss vocational education and training (VET) and a summary of the initial thoughts that led to the study's inception, main aims, materials, and methods are given in the following pages.

### Swiss vocational students – a risk population

> *Happy and confident adolescents are most likely to grow into happy and confident adults, who in turn contribute to the health and well-being of nations.*
>
> Mohan Rao

In Switzerland (including the French and the Italian speaking parts of the country), Austria, Germany and Liechtenstein, vocational education and training (VET) is an important part of the education systems and serves as the primary gateway to numerous occupations. The majority of all secondary school diplomas in Switzerland (74%) are granted to students with VET [1]. VET serves as the primary gateway to numerous occupations. Most students begin at the age of 16 or 17. Swiss VET combines apprenticeships in a company and vocational training in a school; students work three to four days a week in a company and attend a vocational school on one to two days a week. While apprentices receive a limited salary for their work in the company, they often have equal workloads in terms of working hours as well as responsibilities similar to adult employees. The VET systems in the other German-speaking countries are very similar to the Swiss system, and a vocational qualification from one country is generally also recognized in the other states within this area.

Compared to regular high school students, vocational students must face new challenges that arise from the transition to a vocational school and from the dual need to balance academic and job-related requirements [2]. Research has shown that vocational students are especially at risk for stress-related health complaints including depression, insomnia, and substance abuse [2]. Gerber et al., as mentioned earlier, found that one-third of this population already indicated mild school- and job-related burnout symptoms, whereas 16% show strong, and 7% clinically relevant symptoms [3].

Although conceptual diversity in PE across different cultural and educational systems is a common phenomenon [4], health has become an increasingly important topic [5]. Bearing in mind that an expanding body of literature suggests that adolescence is a vulnerable period for the development of psychiatric disorders [6], the need to promote mental health in society is receiving increasing attention at national and international levels

[7]. Growing awareness of the long-term negative consequences of stress has resulted in governments increasingly looking to schools as a setting for promoting resilience as defined as the ability to recover from or adjust easily to misfortune or change in young people. At the same time, it appears that PE may have the potential to provide educative experiences through physical activity [8]. Therefore, the promotion of mental health within PE is almost universally used to legitimize its place in the school curriculum [4]. For instance, in Switzerland, the new PE curriculum for vocational students explicitly addresses stress management as an issue, because stress-related diseases in working life have become a major concern among young professionals in the country [2].

**EPHECT – development and conception of an idea**

Given the described background of Swiss VET students, the health agent of the VET school Rüti asked for a stress management program.

Most existing in-school coping training programs for adolescents are based on theoretical lessons in a classroom setting. The lessons are usually delivered by psychologists or trained study personnel [9,10]. In contrast, in PE, the opportunity arises to integrate both theoretical and practical experiences of stress by having the students solve challenging tasks, which replicate stressful situations (such as two-against-one game situations or falling backwards from a box onto a mat). This approach facilitates experiential learning in which the new coping skills can be learned through active reflections on actual experiences in the gym [11]. The idea is that students are confronted with seemingly impossible or stressful tasks in PE, so they are required to use appropriate coping skills. In a short reflection after the task, adaptive and maladaptive coping strategies (e.g., positive vs. negative self-talk) are discussed to reinforce the newly learned skills. Furthermore, if students must reflect on their own stress responses, it can increase their mental health awareness.

It has long been hypothesized that PE, in addition to promoting physical fitness, also teaches coping and other life skills [4,12]. In a comparison of cross-national PE-curricula, Pühse and Gerber showed that health education is a core element of the PE syllabus in most countries [4]. Recently, Thorburn, Jess, and Atencio have mentioned that similar to England and New Zealand, for example, new policies for PE in Scotland emphasize health and well-being even more than before [13]. In Switzerland, stress management is a major focus of the new PE syllabus of VET students [14]. This syllabus was developed implementing findings from national health surveys showing that stress-related problems in the workplace are increasingly common among young professionals in Switzerland. This increase in focus on the teaching of life skills in PE curricula is in stark contrast to the fact that it is usually absent from PE teacher education. Specifically, PE teachers have no professional education on regarding how to integrate psychological theory into pedagogical practice [7]. This is a lost opportunity, since PE provides an excellent background for the integration of the teaching of life skills in step with practical experience.

Therefore, EPHECT was specifically designed for implementation in PE class. The provision of intervention materials, an online platform, and workshops enables PE teachers to implement the coping training on their own. The advantage of implementing the program through PE teachers is that the PE course is barely affected (the contents of the program are designed for seven different sports and can be added to regular motor skill training). This often plays an important role for schools and teachers in deciding on longitudinal health interventions implemented within their syllabus, since sooner or later among most intervention programs, the question of funding in the long run arises.

**Pilot study – EPHECT I**

The EPHECT I study has the design of a quasi-experimental study.

Participants of the large-scale pilot study EPHECT I were adolescents recruited from two vocational schools located in the cantons of Zurich (intervention school) and St. Gallen (control school). Baseline data was assessed in autumn 2010 with a follow-up in summer 2011. Both schools were about the same size and the sample at baseline was N=1,244 (M = 17.98 yrs., SD 1.36; 531 females). Only second through fourth grade students were included to ensure that all participants were of legal age. The surveys took place in a class setting during PE and were led by trained data collectors, who were not previously acquainted with the students.

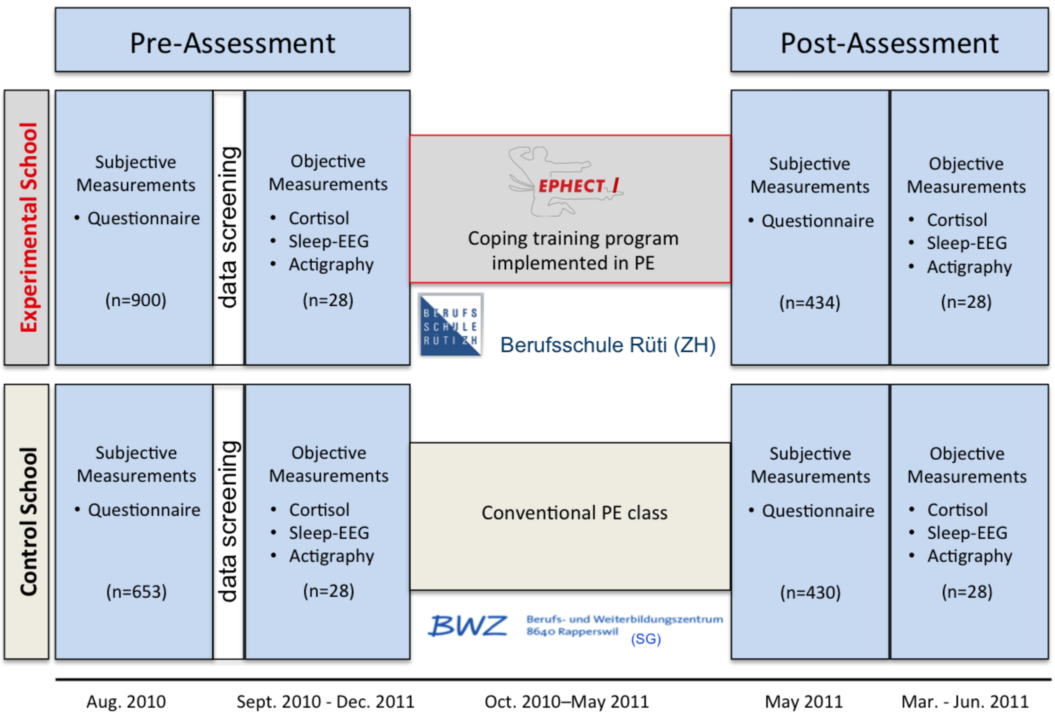


**Figure 3.1. Schematic representation of the research design of EPHECT I**

Based on the psychological questionnaire at baseline, a sub-sample of 56 students was recruited for participation in the physiological testing using a cluster analysis. The sub-sample consisted of 28 students from each school (50% high stress/low stress; 50% poor coping skills/adaptive coping skills; 50% good sleep/bad sleep quality; 50% males/females). Before the data was collected, the psychological questionnaire (paper-and-pencil) was given to five classes at a VET school located in the region of Basel. A summary of the procedure of the EPHECT I study together with the group sizes for the specific part of the study are shown in Figure 3.1.

The general aims of EPHECT I were to measure stress, sleep, and physical activity subjectively and objectively, as well as coping and different aspects related to mental well-being and to analyze their relationship. These measurements were taken before and after the implementation of the intervention. Another parameter that was measured was intervention fidelity, such as, student and teacher compliance consisting of measuring the completeness and accuracy of the implementation of the lessons, reflections, participation and homework.

*EPHECT-intervention*

The study material for EPHECT I was developed in 2010. It consisted of two documents, a teacher manual and a workbook for VET students (Figure 3.2), and accompanying online materials provided on the homepage www.ephect.unibas.ch. In brief, the intervention was developed from a series of field-tested, school-based stress management programs [9,15–20]. Components of these programs were adopted and subdivided into eight modules (Table 3.1), which are implemented in regular PE classes by the PE teacher. While module 1 addresses basic knowledge about stress development, the following six modules focus on aspects related to emotion- and problem-focused coping, including functional and dysfunctional thinking styles, problem solving, social support seeking, and relaxation techniques. Finally, module 8 is designed as a closing event, in which the students get the opportunity to apply the learned contents.


**Figure 3.2. Intervention materials**
Training booklets for teachers and VET students as part of the study material

An important feature of the program was that it had to be possible to be seamlessly incorporated into the existing PE syllabus, as it was expected that this would increase teacher compliance. Therefore, teachers had two weeks to implement a module/teaching lesson into their PE classes.

The main aims of PE classes, which are promoting motor skills and participating in a diverse set of sports to acquire sport-based knowledge and experience, was not to be changed by the EPHECT program. Instead the PE class should be enriched by experiences that allow the learning of socially relevant life skills. Therefore, the coping training was not supposed to take longer than 20 minutes and can be used within the context of seven different sports, namely football, judo, swimming, gymnastics, juggling, acrobatics, dancing, and roller sports. The coping training program was supposed to be understood as a recommendation for PE teachers from which they were advised to deviate, depending on the individual psychological and personality needs of their students.

**Table 3.1**
Structure and contents of EPHECT I and EPHECT II

| Module | Description |
|---|---|
| **M1** | Experience and understand stress |
| **M2** | Counterproductive thoughts and actions |
| **M3** | Eliminate sources of stress - problem solving strategies |
| **M4:** | Develop mental strength - dealing with negative thoughts and emotions |
| **M5** | Relax – Take it easy – e.g., progressive muscle relaxation, breathing technique, yoga |
| **M6** | Manage stress together - social support |
| **M7** | Successful time management - time- and barrier management |
| **M8** | Summary and closing event – e.g., rafting, climbing, biking with the class |

To allow a transfer of the learned coping skills into every day and professional life, the practical exercises were complemented by a reflection period guided by the teacher. The teacher briefly discusses with the students (a) how the tasks relate to the regulation of stress, and (b) what can be learned from these experiences for coping with everyday stressors (e.g., arguments with family members, pressures from peers, occupational demands).

To limit the time necessary for imparting theoretical knowledge during PE lessons, each student received an EPHECT workbook. The workbook contained eight chapters (each corresponding to a module), which all started with a short story to catch students' attention, followed by a summary of the most important theoretical information, self-tests, and reflection tasks. The reflection tasks aim to stimulate a transfer of learning from PE class to everyday and professional life, encouraging students to experiment with these coping strategies within their daily routines. Via a practice log in the workbook, students can plan and document their attempts (Figure 3.3).

For instance, in Module 1 (Experiencing and understanding stress), students are taught that stress is a form of imbalance, learn about possible warning signs, and fill out a stress test as well as a test for warning signs. Further questions to reflect on are: "*Think about what stresses you in everyday life*", "*How do your family/friends know that you are stressed*?" "*Which of your stress reactions do you want to get a grip on*?" These homework tasks are designed to increase students' awareness of their own stress situations and their responses to stress.

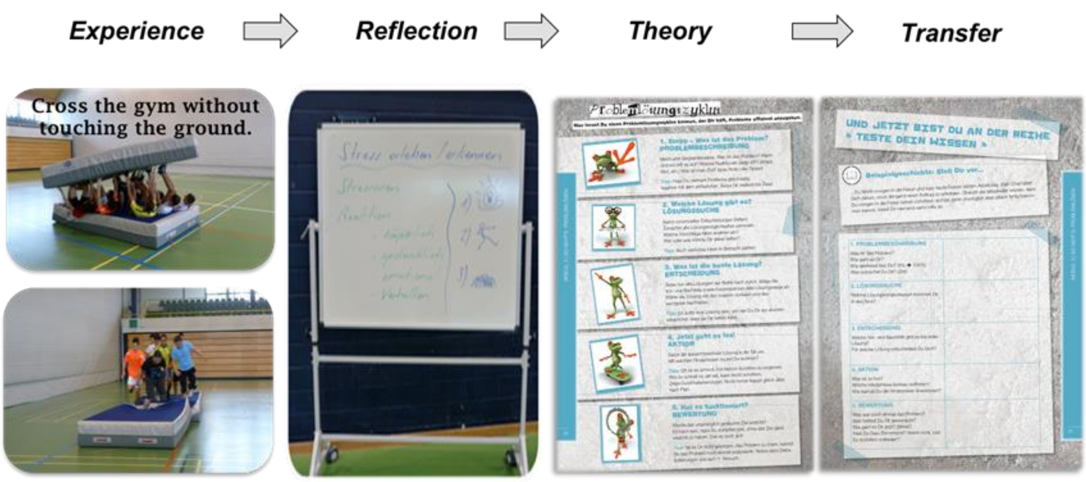


**Figure 3.3. EPHECT and Kolb`s experiential learning cycle**
EPHECT program procedure that facilitates the transfer of learned coping skills from practical experience to life in general.

In contrast, in Module 7 (Successful time management), the goal is to get students to reflect on how they spend their time. The workbook provides a week plan. Students are asked to note time-consuming activities to consider whether unproductive activities could be streamlined. The text discusses the advantage of a to-do list and the importance of formulating clear and achievable goals. The background is that in PE-class, they agree on a goal (e.g., a distance of 30-minutes run). Now, students need to formulate an overall goal and sub-goal, as well as possible barriers and counter-strategies. With their weekly plan, they can try to figure out when best to implement training time. Students were able to practice individually or in groups and evaluate their progress on the goal they had individually selected. They were encouraged to ask for guidance from the teacher as to how to set goals and sub-goals, as well as advice for training related to their goals. The results of their progress were documented in the workbook. The PE grade includes all aspects of this (progress of goal setting, planning and implementing of training, achieving sub-goals and overall goal, absolute distance of 30-minute runs).

In summary, there are modules in which the homework was designed simply to increase students' knowledge and awareness about a specific issue (e.g., Module 1); and there are modules in which the homework task can be part of the PE grade (e.g., Module 7). However, the booklet functions as a progress portfolio for the students. Therefore, teachers are advised to control for homework completion, but the individual process and experiences gained by the students are not evaluated by the teacher, unless the student asks for it or discusses it in the reflection session. The reason for this is that students might not document their individual reflections on sensitive issues, if they are aware that the PE teacher is going to read it afterwards.

A detailed description of the contents of the respective module of the program is given in Chapter 7 (please see Table 7.1).

The main problem with EPHECT I was teacher compliance, mainly because the program was mandated for the entire school by the health agent. A recommendation for future uses of the EPHECT program is to use the training only in classes where the teacher volunteered to participate. This principle was implemented in EPHECT II, which allowed much better compliance than the one found with compulsory implementation such as in EPHECT I.

**Follow-up study – EPHECT II**

The EPHECT II study has the design of a cluster-randomized controlled trial.

In the EPHECT I study, we found that the level of implementation could not be held high over all classes and teachers. Therefore, EPHECT II was designed at a smaller scale to be better able to control for the specific implementation of the stress management program, which would lead to better data. For EPHECT II, a research design was implemented, as shown in Figure 3.4, to evaluate the effectiveness of the stress management program in a well-controlled sample. Only a few psychological aspects were asked for in the questionnaire (socio-demographic background, PA, sleep: ISI, stress, coping, burnout, evaluation of student compliance). Further data collection included qualitative interviews and classroom observations. No objective measurements were taken.

EPHECT II contained qualitative and quantitative parts. The latter ones are part of this dissertation and have been published, while the qualitative data analysis has not yet been published. EPHECT II was designed to improve methodological problems found when EPHECT I was implemented.

For this smaller, improved EPHECT II study, eight classes of the former control school were randomly selected to participate, four of them implementing the PE-based coping training program, the other four classes receiving regular PE lessons (Figure 3.4). The selected classes were first-year classes, which mean that they did not participate in the previous pilot study and their parents were required to give informed consent for their underage children to participate in the study.

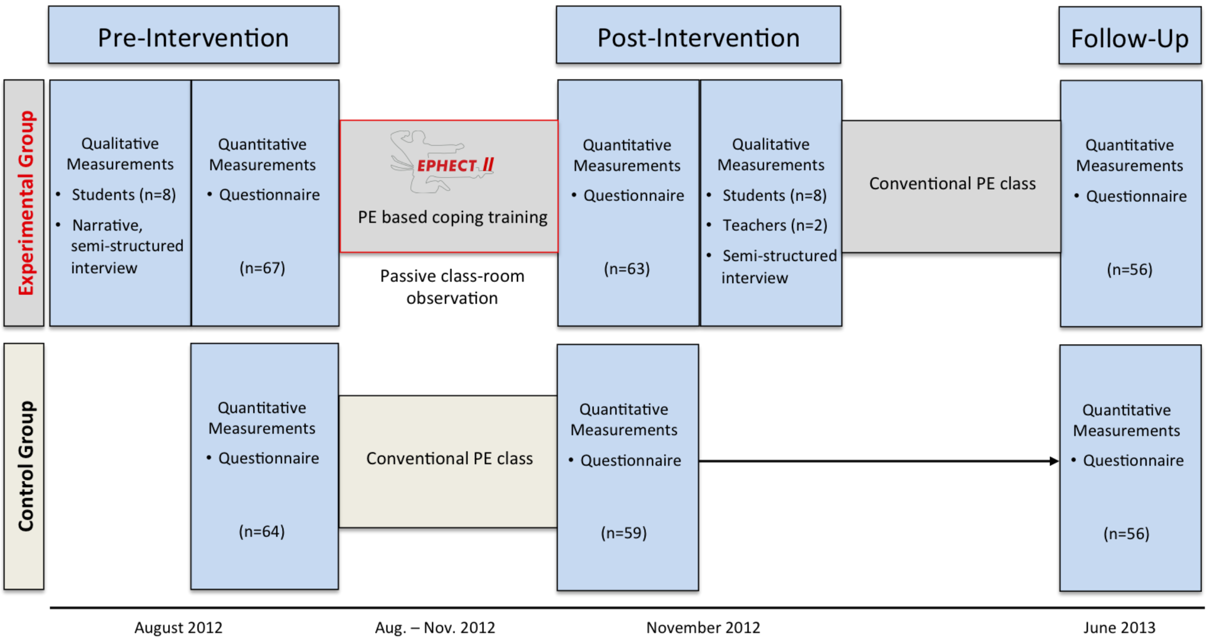


**Figure 3.4: Schematic representation of the research design for the EPHECT II study**

In contrast to EPHECT I, where teacher participation was mandatory, only teachers who volunteered to participate took part in EPHECT II to ensure better teacher compliance. Since EPHECT I showed that with scheduled bi-weekly implementation, it was easily possible that four weeks elapsed before the next module, due to unforeseen schedule changes and breaks, a weekly implementation of modules was mandated for EPHECT II.

### Revision of program and promotion – EPHECT III

Based on evaluation of EPHECT I and especially EPHECT II (class room observation, interviews with students and teachers), a revision of study materials with an expert group, consisting of sport scientists, VET-PE-teachers, sports psychologists, psychologists for children and adolescents, and mental trainers was performed. The program is promoted in teacher workshops for Swiss vocational schools. The promotion consists of an individual cover letter to the school principal with example booklets, conferences, and a teacher magazine. The program was shortened from 8 modules in EPHECT I (including 12 teaching units) to 6 modules in EPHECT II (one teaching unit per module) (Table 3.2) that should ideally be implemented weekly, but in any case within the same school year. There are optional repeat and in-depth modules available that can be implemented at later time points and/or school years. Module 1 teaches the students the most relevant physiological, psychological, and behavioral stress reactions and how stress develops. The subsequent 5 modules teach various aspects of emotional and problem-focused coping strategies. Again, the program can be used within the context of seven different sports, namely football, judo, swimming, gymnastics, juggling, acrobatics, dancing, and roller sports.

**Table 3.2**
Structure and contents of EPHECT III

| Module | Description |
|---|---|
| **M1** | Understand and experience stress – basics of physical and emotional stress response |
| **M2** | Successful time management – time- and barrier management, mindfulness training |
| **M3** | Develop mental strength - dealing with negative thoughts and emotions |
| **M4:** | Get emotions under control – emotion focused coping |
| **M5** | Eliminate sources of stress – problem focused coping |
| **M6** | Manage stress together - social support |

## Instruments and measurement tools

A psychological questionnaire was used in EPHECT I pre- and post-intervention to assess the following topics: socio-demographic data, activity behavior, stress, coping, well-being, and quality of life. Furthermore, to evaluate the effectiveness of the implementation of the training, students as well as teachers from the intervention school completed evaluation questionnaires post-intervention. In addition, physiological measurements were conducted of 28 students from each intervention and control school. These students were selected based on psychological functioning. Half of these students had a high-risk profile (i.e., high perceived stress, poor coping skills, and sleep quality), whereas 50% had a low-risk profile including low stress. The instruments relevant for the research questions are described in more detail below.

For the EPHECT II study, a psychological questionnaire was administered to assess the following topics: socio-demographic data, physical activity behavior, perceived stress, coping skills, and sleep quality. Questionnaires were administered before, immediately after, and again 6 months after the intervention.

### *Demographics and social background*

Students provided information about age, gender, and the financial situation of their families compared to their peers, which provided a measure for socioeconomic status (SES).

SES was assessed with a 5-point scale ranging from 1 (much worse) to 5 (much better). These variables were used as control parameters.

*Subjective physical activity behavior*

To assess self-reported PA, participants indicated how many days they had engaged in vigorous physical activity over the previous week. The response categories ranged from 0 to 7 days. In addition, participants were asked to indicate the average duration (per day) for the days they engaged in these activities. Physical activity frequency multiplied by duration yielded hours of weekly exercise and sport. Moderate physical activity was assessed in a similar way. Both items were taken from the International Physical Activity Questionnaire (IPAQ: www.ipaq.ki.se) Part 4, questions 22–25. The IPAQ itself (German version [21]), measures daily PA, exercise and sport participation across five different domains (work, transportation, household, leisure, sedentary activities). Evaluation of the reliability and validity of IPAQ has been performed in several studies [21].

*Subjective sleep*

Pittsburgh Sleep Quality Index (PSQI) [22]: Participants were asked to think of two typical weekdays within the last two weeks and rate the following sleep items. For evenings, participants answered questions on an 8-point Likert scale about tiredness during the day (8 = not at all tired), concentration during the day (8 = very good concentration), and mood at bedtime (8 = very good mood). For mornings, the questionnaire asked about waking mood (8= very good mood), sleep quality (8 = very good sleep quality), and feeling restored (8 = completely restored), using the same scale. In addition, information about sleep onset latency (SOL) (in minutes), number of awakenings (WASO), and total sleep time (TST) (in hours and minutes) were reported.

Insomnia Severity Index (ISI): Additionally, participants completed four items of the ISI [23]. The items refer in part to the DSM-IV criteria for insomnia DSM-IV-TR criteria for insomnia, asking participants about difficulty falling asleep, difficulty staying asleep, and early morning wakening. A fourth item queried current sleep satisfaction. 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.

*Stress and coping*

Adolescent Stress Questionnaire (ASQ): The ASQ is a measure of perceived general stress and has good psychometric properties (internal consistency, external convergent/divergent validity and test-retest-validity [24]. Several studies validating the reliability of this questionnaire have been demonstrated in previous studies [25]. Originally, it consisted of 58 items representing 10 subscales. In this study, a shortened version with 30 items of the ASQ-test was used with 3 items per subscale and highest factor loadings [24]. Answers for each stressor were given using a 5-point Likert scale ranging from 1 (not at all stressful or irrelevant) to 5 (very stressful). The Stressverarbeitungsfragebogen für Kinder und Jugendliche (SVF-KJ) refers to classical transactional stress theory and differentiates between adaptive (emotion- and problem-orientated) and maladaptive coping strategies. While adaptive coping strategies improve psychological functioning, this is not the case with maladaptive coping styles. Unfortunately, many of the maladaptive coping styles, such as passive avoidance or sleep medication, are highly effective in reducing symptoms in the short-term. The SVF-KJ has proven to be a valid instrument in previous research [16]. Each of the nine coping dimensions is recorded with four items (36 total) on a 5-point scale ranging from 1 (under no circumstances) to 5 (in all circumstances).

*Psychological functioning*

To collect data about depressive symptoms, the shortest version of the Allgemeine Depressionsskala (ADS) [26] was used, which is a German version of the CES-D. The 15 items assess cognitive, emotional, motivational, behavioral, and somatic aspects associated with depression. The 4-point Likert scale ranges from 0 (< 1 d/wk) to 3 (5-7 d/wk). This instrument has been validated in previous studies with adolescents [27]. Satisfaction with life was measured with the Satisfaction with Life Scale (SWLS) [28]. This instrument uses three items to evaluate the overall satisfaction with adolescents' lives using a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Validity and reliability have been established with various populations [29].

Low body satisfaction and physical self-perception as well as maladaptive eating attitudes and extrinsic sport motivation are related to social physique anxiety [30]. The Social Physique Anxiety questionnaire (SPA) has proven to be a valid instrument in previous research [31] and was especially useful with adolescents [32]. Three of the twelve items were used and answers were given on a 7-point Likert scale ranging from 1 (not at all) to 7 (totally). To assess burnout, the Shirom Melamed Burnout Measure (SMBM) was used, which contains 14 items [33]. These items operationalize the three subscales of being physically fatigued, cognitively worn-out and emotionally exhausted. All items used a 7-point Likert scale varying from 1 (almost never) to 7 (almost always) for answering. The psychometric characteristics of the SMBM are comparable with the Maslach Burnout Inventory, which is the most common instrument assessing burnout [33,34].

*Physiological measurements*

Actigraphy: A digital movement-measuring instrument (actigraph) was attached at the participants' non-dominant wrist for three consecutive days and nights. The commercially available tool (SomnowatchR; Somnomedics, Randersacker, Germany) registers every movement above 0.012 g in a biaxial direction. All students taking part in the physiological measurements registered their amount of activity in a physical activity log. In the evenings, students rated the amount of physical activity in which they had engaged during the previous day, and the approximate time when physical activity and exercise had taken place. A portable sleep-EEG device (Fp2-A1; electrooculogram; electromyogram; SOMNOwatchTM, Randersacker, Germany) was used to assess sleep objectively.

Salivary cortisol levels: Cortisol measurements were also taken, but are outside the scope of this PhD thesis.

*Assessment of intervention fidelity*

In accordance with Dane and Schneider [35], the assessment of intervention fidelity focused on the quantity of program delivery, quality of program implementation, and the perceived responsiveness of the students. The students answered five questions regarding program awareness and whether or not they used the student booklets. They also summarized what they learned from the project. Teacher evaluation of the program: The teachers rated the degree of implementation in every class they taught and indicated whether it was possible to discuss the theoretical background with the students. Teacher perception of the program: In a different questionnaire, teachers were asked how they liked the teacher booklets, if they would improve any of the modules, and to what degree they liked the implementation workshop beforehand.

*Statistical analysis*

The following methods were selected for statistical analysis using SPSS (Statistical Package for the Social Sciences) version 20, Amos (Analysis of Moment Structures) version 16 and Mplus version 6.12: Descriptive statistics, analyses of covariance, hierarchical regression analysis and structural equation models. For qualitative data analysis, outside of the scope of this dissertation, the software MAXQDA 11 (VERBI Software, Berlin, Germany) was used.

*Ethical considerations*

The local ethical committee (EKBB) approved the study with no ethical objections. Ethical approval was also given by the ethical committees of the cantons Zurich and St. Gallen. The respondents have been informed that their participation was voluntary and that they could decline participation at any time.

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# CHAPTER 4

## The relationship between physical activity and sleep from mid adolescence to early adulthood. A systematic review of methodological approaches and meta-analysis.

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# THE RELATIONSHIP BETWEEN PHYSICAL ACTIVITY AND SLEEP FROM MID ADOLESCENCE TO EARLY ADULTHOOD. A SYSTEMATIC REVIEW OF METHODOLOGICAL APPROACHES AND META-ANALYSIS


## ABSTRACT

Physical activity is considered an effective, non-pharmacological approach to improve sleep. However, the accurate measurement of physical activity and sleep among adolescents is fraught with challenges. Additionally, comparing the results of different studies is often difficult due to the diversity of assessment tools, analyses and data reporting procedures used. While previous reviews have considered variables that may confound this relationship, this systematic review examines the variations in measurement methods. Based on this overview, a meta-analysis was performed to assess possible influences of the various approaches on effect sizes. Twenty-one studies were included in the systematic review, of which 12 were appropriate for meta-analysis. For this, four subgroups were formed: subjective physical activity and subjective sleep, objective physical activity and subjective sleep, subjective physical activity and objective sleep, and objective physical activity and objective sleep. The majority of studies used subjective measures, often with unknown reliability or validity. Few studies employed objective tools to measure sleep. The results suggest that adolescents with higher subjective and objective physical activity are more likely to experience good sleep subjectively and objectively. More studies employing subjective and objective measures for both physical activity and sleep are needed. Researchers should take into account several assessment factors unique to the adolescent population.


**Key words:** Adolescents; Assessment tools; Exercise; Insomnia; Meta-analysis; Methods; Physical Activity; Sleep; Systematic review; Young adults

## INTRODUCTION

Sleep is of the utmost importance to all areas of adolescent functioning, including academic, psychological and behavioral [1-4]. At the same time, adolescence is a period of vulnerability for the onset of psychiatric illnesses, which may be induced or exacerbated by disturbed sleep [3]. However, although according to the national sleep foundation adolescents still require about eight to ten hours of sleep per night to function best, the majority of adolescents does not achieve the recommended amount [3-5]. Insufficient sleep among adolescents is usually attributed to interactions of intrinsic factors such as puberty, and its associated physical, psychological, and social changes [3], with extrinsic factors such as school start times. Physical changes include circadian and homeostatic components of sleep, which influence the sleep-wake cycle, as well as sleep timing, duration, and architecture [5,6]. In other words, biological sleep patterns shift over the course of adolescence toward later times for both sleeping and waking, leading to a greater gap between sleep duration on school-nights and on weekend-nights [7,8]. This pattern is reinforced by the efforts of teenagers, particularly between 14 and 17 years, to achieve independence from parents and make their own choices about leisure activities and bedtimes. Additionally, they alternate between unrealistically high expectations and a poor self-concept, and engage in high risk behaviors, including experimentation with alcohol, cigarettes and marijuana, all of which can increase the risk for depression and sleep disturbances. Lund et al.[9] further showed that the issues of insufficient and disrupted sleep in mid to late adolescence do not end with graduation from high school, but continue into early adulthood (18-24 years). The transition to college or professional life may be particularly stressful [10], and sleep patterns can be one of the first daily habits to change for many college entrants [11,12]. Therefore it is no surprise that daytime sleepiness (20%) and insomnia symptoms (25%) are highly prevalent in this age group [13,14]. Moreover, females' sleep is more impaired than males', a pattern already apparent in adolescence [7,15]. Therefore, the management of sleep problems (so-called sleep hygiene) in adolescents involves among other things increasing total sleep times and improving other environmental factors that impact upon sleep, such as PA.

The term physical activity covers any form of body movement that results in energy expenditure above basal level. Thus, physical activity includes all daily activities, including domestic (e.g., gardening), occupational (e.g., waitressing), and leisure-time (e.g., exercise) as well as active transportation (e.g., bike ride to school) [16]. In fact, there is evidence that regular physical activity is associated with improved psychological functioning in adolescents, including better sleep quality, which refers to an individual's appraisal of how sleep is experienced, including the feeling of being restored [7,17,18]. Moreover, physical activity is both preventive and favored by many physicians and sleep experts as alternative treatment for insomnia [19-22]. The assumption that physical activity promotes sleep can partly be attributed to traditional hypotheses that sleep serves energy conservation, body restoration and thermoregulatory functions, ideas that have guided much of the research in this field (a recent overview of the literature and theories on how physical activity affects sleep has been provided by Chennaoui et al. [23]. Moreover, two very recent publications show that any kind of PA, even in the evening before bedtime, impacts positively on sleep [24,25]. However, it is still unclear exactly how physical activity impacts on sleep and vice versa. Furthermore, while it is a common phenomenon that from mid adolescence to early adulthood physical activity levels decline [26,27], relatively little systematic sleep research has focused on this critical developmental period.

**Aim of systematic review and meta-analysis**

Several literature reviews have focused upon theoretical models that could explain potential positive effects and confounds of physical activity on sleep [23,28,30]. However, there has as yet been no systematic review or meta-analysis with a special and specific focus on the methodology of assessment, and in particular of research covering the period of mid-adolescence to early adulthood.

Additionally, while previous reviews have given detailed consideration to variables such as frequency, intensity, and type of PA, as well as the influences of age, gender and time of day, there has been no review of research on the physical activity and sleep relationship that focusses on the methodology of assessment. Therefore, this article provides a brief overview of the range of measurement tools that have been used to assess physical activity and sleep in the period mid-adolescence to early adulthood (aim 1). Based on this overview, a systematic review is made of past approaches and current methodological trends in assessing the relationship between regular physical activity and sleep among healthy adolescents (aim 2). Then, in a meta-analysis (based on cross-sectional data) we examine how different methodological approaches are related to the observed strength of the relationship between physical activity and sleep (aim 3). Finally, we seek to list some considerations for researchers in this area who are planning to conduct studies regarding dose-response relationships between regular physical activity and sleep in this age group (aim 4).

**The assessment of sleep among adolescents**

Researchers and clinicians have analyzed adolescents` nocturnal sleep using both subjective (indirect) and objective (direct) tools. The former include self-report questionnaires interviews, and sleep diaries [4,31]; the latter cover techniques such as actigraphy [32], portable electroencephalogram (sleep-EEG) [7], and polysomnography (PSG) [4].

Questionnaires have been the most widely used means to assess sleep, preferred by virtue of their cost effectiveness and their ability to capture subjective experience [31]. However, findings based on self-reports are often difficult to compare because of the extreme diversity of the measures used. Moreover, researchers are often uncertain whether participants are providing accurate reports of their bedtimes or sleep quality. Adolescents in particular may report only the most recent, salient, and/or socially desirable patterns [2]. Furthermore, much of the epidemiologic research has been based on established cohort studies that included only a single question about sleep such as “How well do you usually sleep?” [33], or “Did you have sleeping problems during the last night/week” [34]. There has been little validation of such questions against well-validated and established instruments such as the Pittsburgh sleep quality index (PSQI), Epworth sleepiness scale (ESS) or the insomnia severity index (ISI). While it is generally accepted that epidemiological data have the advantage of being based on large and representative samples [28], the samples that are the basis of epidemiological studies on this topic are not necessarily representative of the entire adolescent population (e.g. high-school vs. college students, areas of wealthier and medium household income, voluntariness of participants [35], different age groups and nationalities [35,36].

Subjective information about sleep patterns has also been collected via daily sleep logs (diaries). While sleep logs kept over a period of 1-2 weeks can provide a wealth of information about the consistency of bed and waking times, sleep onset latency, weekend oversleep, feelings of being restored and daytimes sleepiness [4,31], compliance is a challenge with adolescent samples [38]. Despite this potential shortcoming, respondents seem better able to report on current experience than to provide retrospective reports by questionnaire [2]. Thus, sleep logs are generally viewed as more accurate and allow quantitative assessment of sleep length and sleep/wake schedules [2]. Importantly, data from sleep logs are positively correlated with objective measures of sleep, such as actigraphy [2,39] and PSG recordings [40,41].

During the past decade, wrist actigraphy has emerged as a more objective method for estimating sleep duration, sleep efficiency, and sleep timing [42], while being less expensive or invasive than either sleep-EEG or PSG. The devices normally have the size of a wrist watch, but contain an accelerometer that provides information about when a person is asleep or awake. Moreover, actigraphy allows collection of information about sleep patterns over an extended period (24 hours a day over 1-2 weeks) in the adolescent`s typical sleep environment [4]. Furthermore, there seems to be no “first-night effect” because, unlike sleep-EEG, actigraphy does not disturb normal sleep routine [32]. Actigraphy has been used in several studies with adolescents [2,43-45][5] and has demonstrated validity for total sleep time when compared with PSG [42,45].

The “gold standard” in measuring sleep is overnight PSG, a multi-parametric test and common diagnostic tool in sleep medicine. It requires participants to be monitored in a sleep laboratory for one or preferably at least two nights (to avoid first-night effects) by sleep technicians. Typically, 16 specific channels record a range of body functions including brain activity (Electroencephalography = EEG), eye movements (Electrooculography = EOG), muscle activity or skeletal muscle activation (Electromyography = EMG) and heart rhythm (Electrocardiography = ECG) during sleep. These data require analysis by experienced sleep raters. Portable sleep-EEG home devices provide a less expensive alternative to PSG. They usually have one to three channels to assess sleep architecture and sleep continuity, but allow participants to sleep within their familiar surroundings. Recent studies on adolescents with portable one-channel sleep-EEG devices have proved to generate satisfactory data [7,18,46-48]. In particular, sleep efficiency, measured via PSG, seems to be robust to night-to-night variability [49,50]. Similarly, studies on sleep actigraphy have reported high interclass correlations [51,52], even over a longer period of twelve months [52]. While actigraphy, sleep-EEG and PSG can provide more reliable and valid assessments of sleep patterns, they are all relatively costly and time consuming and therefore not optimal for large scale-studies. Moreover, the sleep-EEG recorded on a particular night may depend on the participant's history prior to the recording (e.g., sleep on previous nights, drug use).

In conclusion, there is a wide range of measurement methods or assessing sleep subjectively and objectively among adolescents. However, the results produced are not always congruent, even for the same variable. For example, while questionnaire data on sleep duration seem to correlate moderately with actigraphic sleep duration, questionnaire data on sleep quality show only a low correlation with actigraphic sleep efficiency [53]. This pattern is consistent with research on adolescents where subjective and objective data show weak or inconsistent correlations [48,54].

**The assessment of physical activity among adolescents**

As has been the case with nocturnal sleep research, physical activity levels among adolescents have been assessed using both subjective and objective instruments. The former include self-report questionnaires and interviews [55,56] as well as physical activity logs [57,58]. Subjective instruments enable researchers to gain information about duration, frequency, and intensity of physical activity as well as sedentary behaviors, and light, moderate, and vigorous levels of PA. From these primary data it is possible to derive estimates of energy expenditure or compliance with internationally accepted physical activity recommendations (e.g., of the centers for disease control and prevention (CDC) or American college of sports medicine (ACSM). One retrospective questionnaire that is extensively validated across different population groups is the International physical activity questionnaire (IPAQ) (http://www.ipaq.ki.se/ipaq.htm). Originally, this instrument was developed as a cross-national monitoring tool for physical activity in adults (age range of 15-69 years). Nevertheless, much of the epidemiologic evidence has come from established cohort studies that have included just one or two questions such as “Was physical training performed at least once per week?” [37], “Do you undertake any physical sporting activity after school?” [59] or “Frequency of exercise during one week” [60].

In addition to subjective methods of assessment, there are several techniques for the objective measurement of PA. These can be roughly grouped into calorimetry (doubly labeled water, direct, indirect), physiological markers (heart rate), motion sensors [61,62], and direct observation [63]. Wearable monitors for assessing physical activity include pedometers (steps, distance), accelerometers (movement counts, minutes of moderate to vigorous PA, total energy expenditure), heart rate monitors (energy expenditure), combined accelerometer/heart rate monitors, and multiple sensor systems. The components of physical activity which researchers are currently able to measure with these objective tools include total PA, duration, frequency and intensity of PA, sedentary behavior, light, moderate, and vigorous levels of PA, prediction of total energy expenditure, classification of locomotive activities (walking, jogging, running), walking (number of steps, stride, speed, distance), and posture (lying, sitting, standing) [64]. Although each of these objective measures has its own strengths and limitations, most researchers consider doubly labeled water (DLW) as the “gold standard” for estimating the free-living energy expenditure of humans. DLW is water in which both the hydrogen and the oxygen have been partly replaced with the stable isotopes of oxygen (oxygen-18) and hydrogen (deuterium). As oxygen-18 is lost from the body in the form of water and carbon dioxide ($CO^2$), whereas deuterium is only lost as water, the difference from loss from the body reflects $CO^2$ production over a specified period. This in turn is an index of energy expenditure. Because DLW is both costly and limited to small samples [42], accelerometry is currently the most frequently used method for assessing physical activity objectively [65]. However, it is important to note that most types of accelerometers are not able to assess cycling appropriately and need to be removed before swimming or contact sports. Moreover, compliance, understood as a participants` willingness to follow thoroughly experts` advice and recommendations, is a common issue among this age group. Sirard and Slater [66] found that older high school students may be less willing to participate in research projects, possibly due to time and social constraints. This pattern has been shown independently of students` activity level, race and gender. In fact, most students who not wear an accelerometer as indicated do so simply because they forgot. More girls reported they did not wear the accelerometer because of fashion or social recognition. However, accelerometry is receiving increased attention within this field of research as both physical activity and sleep patterns can be measured with the same device [42].

While it seems that the same variable (e.g., hours of vigorous physical activity per week) assessed via subjective and objective methods correlates moderately to strongly [48,56], the difficulty of comparing across studies lies in the multitude of reported variables referring to physical activity (e.g., physical activity vs. exercise vs. fitness vs. energy expenditure; number of steps vs. hours of PA; moderate vs. vigorous PA; classification of moderate vs. vigorous intensity).

## Methodological issues in the collection of evidence

Reviews have shown that the nature of the relationship between regular physical activity and nocturnal sleep varies considerably [22,28,67]. Although such heterogeneity may be a product of numerous moderating factors such as sex, age, fitness level, sleep quality, and the characteristics of the PA, alternative explanations include the challenges surrounding the accurate assessment of both physical activity and sleep. As described above, the wide range of measurement procedures employed and the use of unvalidated instruments make it difficult to compare findings, to determine a true effect size (meaning that it needs many well-run studies to become more confident about what the true effect size might be, compared to the estimated effect size), to establish a dose-response relationship between physical activity and sleep in this age group, or to monitor the effect of interventions [55,68]. However, currently there is no single or perfect way of measuring either physical activity or sleep in adolescence, since each option has its own limitations. Researchers' choices of assessment method are based on several considerations including research aims, sample size, population, available time and resources [69].

Nevertheless, the first part of this article summarizes some commonly accepted methodological considerations that researchers should be aware of when assessing the relationship between physical activity and sleep among adolescents. Current debates about the validity of subjective versus objective tools are still confined to sleep [2,27,42,53] and physical activity [56,61,64,70] as separate and mutually isolated fields of research. In other words, what is known about how best to assess physical activity and sleep has hardly been considered when assessing the relationship between regular physical activity and nocturnal sleep.

## METHOD

### Search and selection of studies

We conducted a systematic review and a meta-analysis in accordance with the guidelines for preferred reported items for systematic reviews and meta-analysis (PRISMA) [71]. Five electronic databases (Pubmed, SportDiscus, PsychInfo, ERIC, and Web of Science) were searched for studies, using Title, Abstract, and MeSH terms (medical subject headings) to identify relevant publications that contained at least one term from each of the three categories of search terms used (last search June 2014):

- adolescents / OR adolescence / OR pupils / OR students
- AND exercise / OR physical activity
- AND sleep / OR insomnia

The searches were limited to English and German language publications. Titles and abstracts, and if necessary full text articles, were examined by the first and second authors independently to determine if the publications were eligible for inclusion in (a) the systematic review and (b) the meta-analysis. The reference lists of the remaining publications were searched for potentially relevant and eligible studies missed in the database searches. If abstracts of studies met the eligibility screening criteria but full texts could not be retrieved from the databases, first authors were contacted and asked for a copy of their publication. Finally, full text articles were read and examined for inclusion in the systematic review. Studies were included if they met the following criteria:

- The data reported gave information about the relationship between physical activity and sleep.
- The reported mean age of participants was in the range 14-24 years. This particular age range was chosen as sleep data for younger adolescents often rely on parent reports. Additionally, by the age of 14 adolescents usually decide on their bedtimes themselves. Moreover, the accurate measurement of physical activity in children and younger adolescents is fraught with challenges, given their complex and multi-dimensional physical activity patterns.

- Studies that assessed insomnia characteristics in the general adolescent population as an indication of sleep quality were included. On the other hand, studies were excluded if they specifically contained participants with psychiatric, mental, or physical illnesses.
- PA was performed regularly (thus, exclusion of acute exercise studies, fitness tests) as regular exercise represents a non-pharmacological treatment for poor sleepers [23]. In contrast, most acute exercise studies have examined exercise and sleep only on one or two days [30]. Moreover, in a recent comprehensive literature review, Chennaoui et al. [23] were able to show that the possible underlying effects of acute and regular aerobic physical activity on sleep as indicated by several physiological markers (e.g., body core temperature, growth hormone, circadian rhythm, autonomic nervous system) are not in all respects congruent.

No study was excluded on the basis of study design. If the first two authors of the present study were unsure how to classify a study, the third or last author examined the publication again, and agreement was reached by consensus.

**Data extraction and coding**

In a first step, data from all the included studies were summarized by the first author. The second author checked the accuracy of the data extracted. These data contained information about author, year of publication, sample (sample size, gender, mean age, country), measurements (detailed information about assessment of physical activity and sleep including whether subjective and/or objective), data analyses, and results. Questionnaires (all involving self-report), logs/diaries, and a comparison of athletes and non-athletes/controls were coded as subjective PA. Studies of athletes were included, as they engage in regular PA, and groups of athletes/non-athletes were formed post-hoc. In contrast, studies assessing fitness levels were excluded because physical fitness is a physiological attribute that is influenced by other variables aside from PA, such as sex, age, genotype and other behavioral determinants [72,73]. Lindwall et al. [73] speculated that self-rated physical activity and fitness level may act independently on mental health outcomes, and that the patterns of association between physical activity and mental health may be different from the association between fitness and mental health [16,74].

In one particular study, the participants of a running group were compared to a non-running group. Although each group was accompanied by a member of the research team, we classified physical activity in this study as subjectively assessed. physical activity behavior was directly observed but no standardized observation tool was used [18].

Pedometers, and accelerometers were coded as objective PA. With regard to sleep, questionnaires and logs were coded as subjective measures of sleep. Sleep-EEG (assessed at home) was coded as objective sleep.

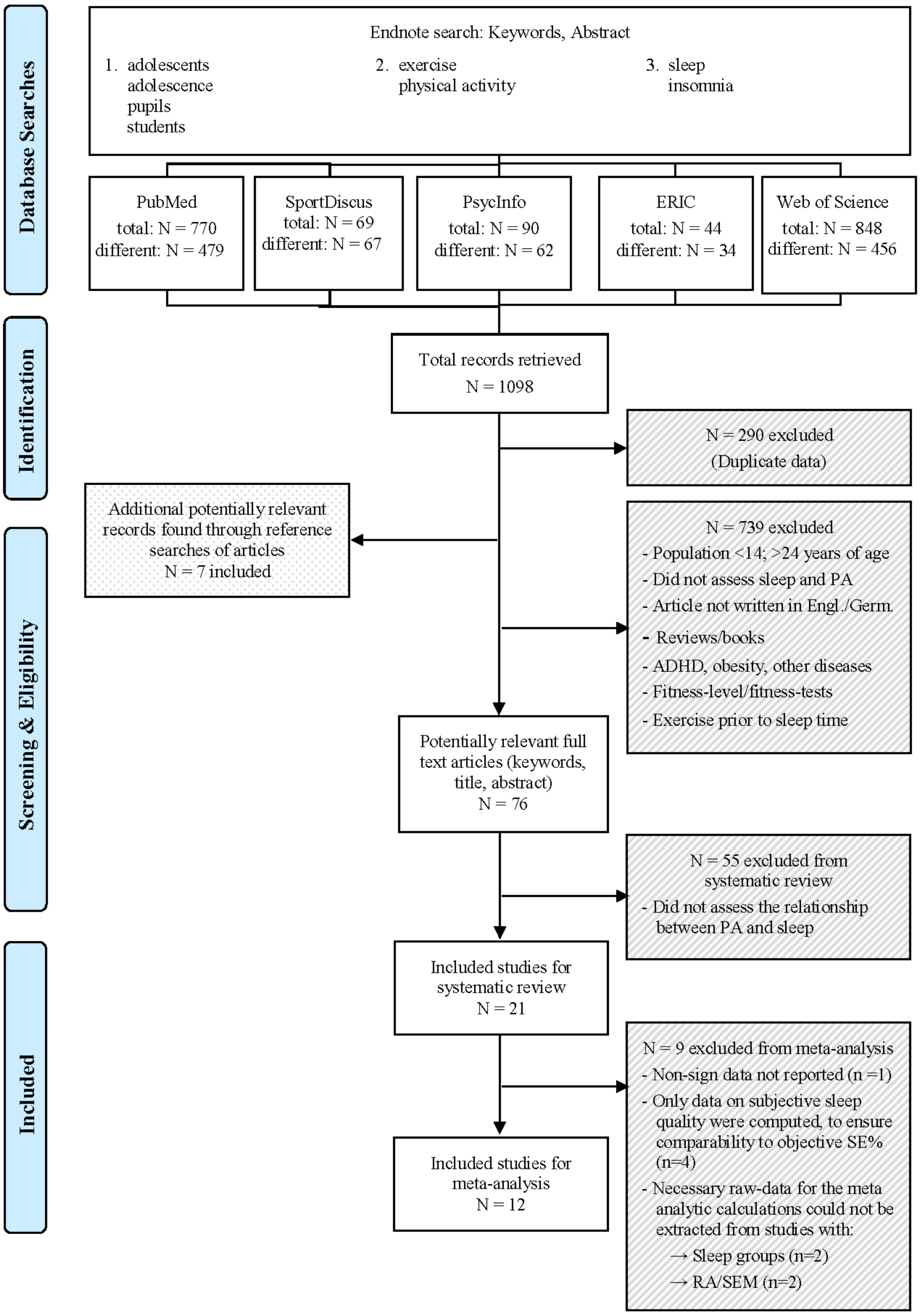


**Figure 4.1. Flow chart of systematic review process and studies included in the meta-analysis.** Abbreviations: ADHD: attention deficit disorder, N/n: number of studies, RA: regression analysis, SEM: structural equation model, sign.: significant, total: N/different: N: refers to the fact that some studies appeared more than once within the database search.

**Meta-analytic calculations**

All meta-analytic calculations were performed with the software comprehensive meta-analysis [75]. We calculated the standardized mean difference (95% confidence interval (CI)) in subjective/objective sleep variables between the physically active and control groups. If studies reported multiple sleep variables referring to subjective sleep quality, the average effect size of the reported outcome was used as the subjective sleep indicator. This is a commonly used strategy because multiple outcomes of the same participants are not independent and it would be inappropriate to treat them as such when combining effect sizes across studies [76]. The extraction of only one outcome, however, could distort the overall results of a study, as reported effect sizes within a single study can vary considerably. For objective sleep, we extracted sleep efficiency (SE), which is calculated as ratio between the factual sleep time (min), divided by the time in bed (TIB min) minus SOL (min), and minus WASO (min).

Because a main aim of this study was to examine the influence of different assessment methods on the strength of the relationship between physical activity and sleep, we performed analyses on four subgroups:

1) objective physical activity and objective sleep

2) objective physical activity and subjective sleep

3) subjective physical activity and objective sleep

4) subjective physical activity and subjective sleep

If one study reported more than one assessment method, the study was included in more than one subgroup. In order to conduct an overall meta-analysis, effect sizes from studies with more than one assessment method were selected according to their first appearance in the above subgroup order. Duplicates were exlcuded.

Effect sizes of .20> $d$ <.49 were considered small, .50 > $d$ < .79 medium, and $d \geq .80$ large [77]. In order to test for heterogeneity, $Chi^2$-tests and the statistical index of heterogeneity ($I^2$) derived from the $Chi^2$-values were computed to evaluate the heterogeneity between studies of each subgroup. $I^2$ values of 0% indicate no, 25% low, 50% moderate, and 75% high heterogeneity (e.g., due to differences in the measurement methods between the studies) [77].

We also employed the $Chi^2$-test, with P-value less than 0.10 indicating significant heterogeneity. Because the observed value was high for one subgroup-analysis [78], we used random effect models in all data analyses.

Outlier detection was performed using absolute deviation around the median (MAD) [79].

A common problem in meta-analytic research is publication bias, which refers to the fact that many studies may remain unpublished because of small effect sizes or non-significant findings [80,81]. A number of publication bias methods have been developed, including selection models and methods based on the funnel plot. However, all publication bias methods are characterized by a relatively low power and are based on strong and unverifiable assumptions; their use does not guarantee the validity of conclusions from a meta-analysis [82,83].

Although there is no precise method for assessing and correcting for publication bias, one way of examining what effect publication bias could have on the results of a meta-analysis is to inspect the funnel plot, which is primarily a visual aid. A roughly funnel-shaped distribution indicates the absence of publication bias, assuming that the largest studies are near the mean effect size, and smaller studies are spread evenly on both sides of the average. In contrast, an asymmetric funnel may reflect a selective publication of studies [76]. Therefore, to assess the risk of potential publication bias, a funnel plot was created for subgroups containing at least three studies. Subsequently, Rosenthal`s fail-save *N* value were calculated [84]. It represents the number of non-significant studies that would be necessary to reduce the effect size to a non-significant value. For an effect to be considered robust by Rosenthal`s criteria, the fail-safe *N* must be greater than the number of studies within the analysis.

## RESULTS

### Description of the search results selection process for the systematic review and meta-analysis

Figure 4.1 illustrates the search flow and the identification of eligible studies. Using the keywords, a total of 808 abstracts were identified, after exclusion of duplicates. The screening of the titles and abstracts produced 70 studies for which the full text was evaluated. Examination of the reference lists of the full texts identified seven additional articles. Further screening resulted in a total of 21 studies which were considered eligible for the systematic review. Eight of these studies had to be excluded from the subsequent meta-analysis, because statistical information necessary to calculate an effect size could not be extracted.

### Systematic Review

*General description of study population, design, measurements*

Table 4.1 summarises the studies included in the systematic review. A more detailed description of these studies is provided as supplemental online material (Table 4.2). The studies comprised 16,549 adolescents, with a median sample size of 416 (range 11 – 8,000) per study. Different populations/age groups were analyzed in four studies [37,58,81,85].

According to the eligibility criteria, we only extracted data for sample members in our specified age range (14-24 years). The mean age was 17.8 years. Two studies involved males only [46,87], one study involved females only [88]. In total, 52% of participants were female. Among studies including females, only one assessed menstrual stage [89].

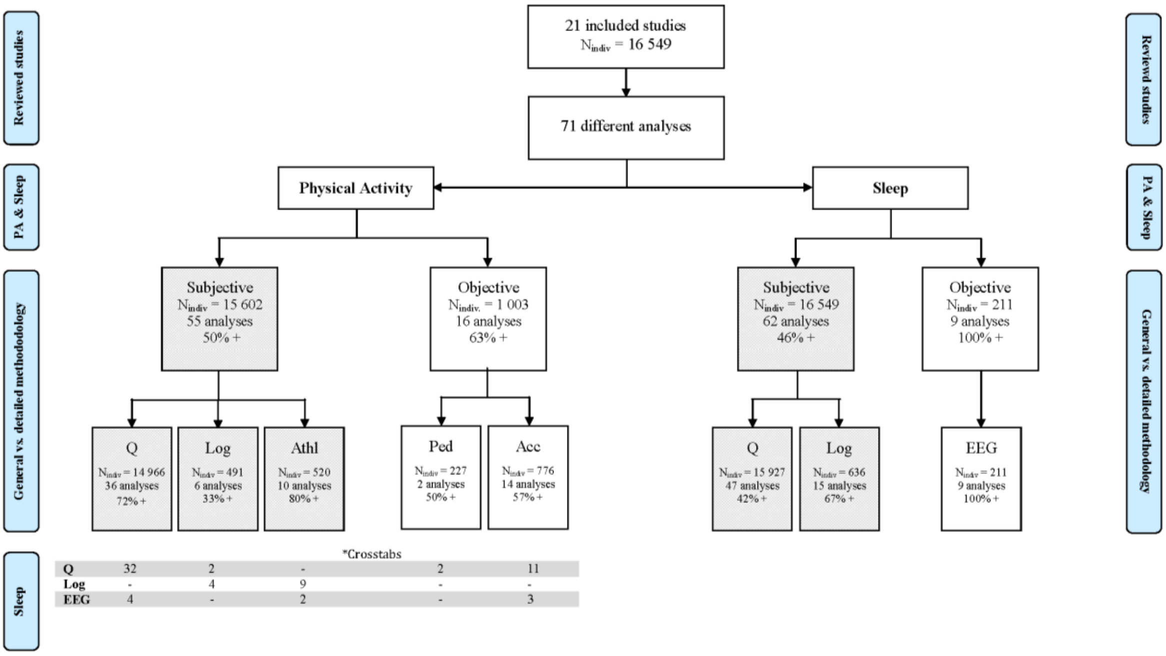


**Figure 4.2. Overview of methodology used in the reviewed studies.**
Abbreviations: Acc: accelerometer, Athl: comparison of athletes and non-athletes/running-group and no running-group, EEG: assessment of sleep via electroencephalogram at home, Log: daily/weekly log, $N_{indiv}$: number of individual participants, + : percentage of findings with positive effect sizes (see Table 4.2), Ped: pedometer, Q: questionnaire, *Crosstabs: crosstabs of all methodological combinations used in the reviewed studies to assess the relationship between physical activity and sleep.

As shown in Table 4.1, the majority of the studies were cross-sectional. One study was longitudinal [18], and used a randomized-control design [18]. In this case, it was decided to include the second measurement, as groups of high and low physical activity were distinguished only after an intervention. Six studies presented more than one statistical analysis based on the same data (e.g., MRA, p (rho), t-test, ANOVA) [7,17,46,48,58,88]. Commonly, groups of high and low physical activity as well as all levels and intensities of physical activity were compared with respect to sleep within the same study. While most studies compared groups (i.e., high physical activity vs. low PA), only seven studies reported continuous variables exclusively (e.g., exercise duration (min/day)) [9,33,37,59,60,86,89], and four studies analyzed both group and continuous measures of association.

Most studies assessed the relationship between sleep and physical activity using at least one subjective measure (85.7%; *n* = 18). Half of the studies (52.2%; *n* = 12) used subjective measurements exclusively [7,9,33,34,36,37,58-60,87-91]. Only two studies combined objective physical activity and objective sleep assessments [48,92]. In five studies, more than one assessment method was used, with either sleep or physical activity assessed subjectively and the other objectively [17,46,18,48,92]. Only one study examined the relationship between physical activity and sleep using both subjective and objective measurement techniques and comparing all combinations with each other [48].

*Description of the physical activity measurements*

Table 4.1 gives a summary of the studies included in the systematic review. A graphical overview of the range of measurement tools that have been used to assess regular physical activity within the reviewed studies is presented in Figure 4.2. Questionnaires were used most frequently (36%; *n* = 11) to assess physical activity subjectively. Of these, one third (n = 4) asked a single question to assess physical activity [7,37,59,92]. Complete versions of validated questionnaires were not used in any of the studies, although three studies employed one or more questions extracted from a validated instrument. Activity logs were employed in three studies [17,58,88], and four studies compared athletes and controls [18,18,46,87]. Objective physical activity was assessed by means of pedometers [78] and accelerometers [48,85,92]. No study used assessment tools such as heart rate monitors, combined accelerometer/heart rate monitors, multiple sensor systems, direct/indirect calorimetry, or the “gold standard” of doubly labeled water. In distinguishing between groups with high and low levels of PA, two studies indicated that their cut-offs were based on recommended guidelines for physical activity (ACSM, CDC) [48,92].

*Description of the sleep measurements*

Table 4.1 gives a summary of the studies included in the systematic review. A graphical overview of the range of measurement tools that have been used to assess sleep within the reviewed studies is shown in Figure 4.2. Subjective sleep quality and quantity was evaluated via questionnaire in 15 studies. The most frequently used instruments were the PSQI [93] and ISI [94]. The PSQI was administered in six studies[9,17,18,46,48,87] and the ISI in five [7,18,48,91,92]. In contrast, four studies (27%) either assessed sleep on the basis of a single question [35,79,83] or asked exclusively about TST [85,86,90]. This latter choice might be of importance as, among 12 studies assessing subjective TST, ten (83%) found no association between physical activity and subjective TST [17,34,46,48,58,60,85,87,90,91]. Moreover, comparing subjective sleep quantity and PA, only 42% reported a positive small to large effect size. In contrast, this relationship was confirmed in 58% of the analyses with subjective sleep quality and PA. Logs were used in 29% (n = 6) of the studies [17,18,48,58,87,88], covering periods from seven to 105 days. Logs were filled out in the mornings and/or evenings on consecutive days, or once per week for several months. In contrast, to assess PA, only 14% (n = 3) used a log.

Assessing objective sleep, five studies assessed sleep-EEG in participants` homes [7,18,46,48,92], whereas examinations in a sleep lab using PSG and wrist actigraphy were not applied among the included studies. These two assessment methods are more frequently used in acute exercise studies [49,95] than in studies assessing regular physical activity and sleep. In summary, only a small range of nocturnal sleep assessment tools was used. However, Lang et al. [48] employed a one-channel sleep-EEG in combination with a wrist actigraphy device, which was used to assess physical activity on the previous days.

**Meta-analysis**

The overall meta-analysis yielded a large overall effect size of $d$ = 0.894 ($z$ = 4.272; $p$ < .001; CI [0.484; 1.305]; $I^2$ = 66.44%) on the influence of physical activity on sleep. Due to the moderate to high heterogeneity, the meta-analytic calculation was repeated after exclusion of a possible outlier [88]. This resulted in a significant reduction in heterogeneity while results show a moderate effect size ($d$ = 0.771; $z$ = 4.163; $p$ < .001; CI [0.408; 1.133]; $I^2$ = 36.52%). However, due to the high methodological heterogeneity (subjective and objective assessments of physical activity and sleep) the overall analysis remains difficult to interpret. Thus, the discussion focusses on the subgroup-analysis.

*Relationship between subjective physical activity and subjective sleep*

Figure 4.3 gives the results and a graphical summary of all subgroup analyses. The subgroup analysis for the relationship between physical activity and sleep where both were assessed subjectively covered 11 studies out of 12, indicating that the most frequently used method to relate physical activity to sleep was through subjective assessment. The subsample comprised 3,144 adolescents, with a median sample size of 56 (range 14 – 1325) per study.

The meta-analysis yielded a large overall effect size of $d$ = 0.943 ($z$ = 4.786; $p$ < .001; CI [0.557; 1.329]; $I^2$ = 70.49%) indicating that higher subjective physical activity is associated with better subjective sleep. Due to the moderate to high heterogeneity, the meta-analytic calculation was repeated after exclusion of a possible outlier [88]. This reduced the heterogeneity in this subsample while results show a similar effect size ($d$ = 0.882; $z$ = 4.684; $p$ < .001; CI [0.478; 1.165]; $I^2$ = 50.92%). However, further sources of variability within this subgroup were not evaluated through moderator analyses. This is because the main focus of this meta-analysis was to examine the effect of methodology in this field of research rather than to find evidence for a relationship between physical activity and sleep.

While in this subsample analysis 45% used a questionnaire to assess sleep quality, only 40% (n = 2) administered a validated instrument. Twenty percent (n = 1) assessed sleep via a single question.

**Table 4.1**
Study characteristics of reviewed articles

| Author (year) | Population | | | Methods | | | | | | | | Results |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nat | Age | N | Assessing PA | | | Assessing sleep | | | Statistics | | |
| | | | | What is assessed | Time frame | How | How | What is assessed | Time frame | Design | Analysis | |
| *Alricsson M et al 2008* [34] | AUS | 16.2 | 466 | Medium-high/none-low PA | Last 3 month | Q | Q | Quantity | Last 3 months | 1,3 | $\chi^2$ | 0 |
| **Armstrong S et al 2009* [36] | USA | 19.9 | 227 | Athletes vs. non-athletes | | Q | $Q^1$ | Quality | habitual | 1,3 | ANOVA | + |
| **Brand S et al 2009* [87] | SUI | 15.4 | 70 | Athletes vs. non-athletes | | Athl | $Log^v$ | Quantity | 2*day for 1 week | 1,3 | ANOVA | 0 |
| | | | | Athletes vs. non-athletes | | Athl | $Log^v$ | Quality | 2*day for 1 week | 1,3 | ANOVA | ++ |
| **Brand S et al 2010* [7] | SUI | 18.6 | 38 | High vs. low VPA | Last week | $Q^1$ | $Q^v$ | Insomnia | Last 2 weeks | 1,3 | ANOVA | 0 |
| | | | | High vs. low VPA | Last week | $Q^1$ | EEG | One-channel (Fp2-A1) | One night | 1,3 | ANOVA | ++ |
| | | | | Level of VPA | Last week | $Q^1$ | EEG | One-channel (Fp2-A1) | One night | 1,3 | MLR | ++ |
| **Brand S et al 2010* [17] | SUI | 17.2 | 434 | Athletes vs. non-athletes | | Athl | $Log^v$ | Quantity | 2*day for 1 week | 1,3 | ANOVA | 0 |
| | | | | Athletes vs. non-athletes | | Athl | $Log^v$ | Quality | 2*day for 1 week | 1,3 | ANOVA | + |
| | | | | Athletes vs. non-athletes | | Athl | $Log^v$ | Quality | 2*day for 1 week | 1,3 | MLA | + |
| | | | | H/VPA/week | Last week | Log | $Log^v$ | Quality | 2*day for 1 week | 1,3 | MLA | 0 |
| **Brand S et al 2010* [46] | SUI | 16.0 | 24 | Athletes vs. non-athletes | | Athl | $Log^v$ | Quantity | 2*day for 1 week | 1,3 | ANOVA | ++ |
| | | | | Athletes vs. non-athletes | | Athl | $Log^v$ | Quality | 2*day for 1 week | 1,3 | ANOVA | ++ |
| | | | | Athletes vs. non-athletes | | Athl | EEG | One-channel (Fp2-A1) | One night | 1,3 | t-test | ++ |
| **Delisle TT et al 2008* [90] | USA | 17.0 | 822 | Low/medium/high MPA | Last week | Q | $Q^1$ | Quantity | Habitual | 1,3 | MANOVA | 0 |
| | | | | Low/medium/high MPA | Last week | Q | $Q^1$ | Quantity | Habitual | 1,3 | MANOVA | + |
| **Gerber M et al 2010* [91] | SUI | 24.7 | 862 | Low/medium/high exercise | Last week | $Q^1$ | Q | Quantity | Habitual | 1,3 | MANOVA | 0 |
| | | | | Low/medium/high exercise | Last week | $Q^1$ | Q | Quality | Habitual | 1,3 | MANOVA | 0 |
| | | | | Low/medium/high exercise | Last week | $Q^1$ | $Q^v$ | Insomnia | Last month | 1,3 | MANOVA | 0 |
| | | | | Lack /no lack of exercise | Last week | $Q^1$ | Q | Quantity | Habitual | 1,3 | MANOVA | 0 |
| | | | | Lack /no lack of exercise | Last week | $Q^1$ | Q | Quality | Habitual | 1,3 | MANOVA | 0/+ |
| | | | | Lack /no lack of exercise | Last week | $Q^1$ | $Q^v$ | Insomnia | Last month | 1,3 | MANOVA | 0 |
| **Gerber M et al 2014* [92] | SUI | 22.2 | 42 | High/low PA | 7 days | Acc | Q | Insomnia | Last month | 1,3 | ANCOVA | ++ |
| | | | | High/low PA | 7 days | Acc | EEG | One-channel (Fp2-A1) | 1 night | 1,3 | ANCOVA | + |
| **Holmberg LI et al 2008* [37] | SWE | 17.3 | 1325 | Exercise/no exercise | Habitual | $Q^1$ | Q | Good/bad sleepers | Last week | 1,3 | LRA (OR) | 0/+ |
| **Kalak N et al 2012* [18] | SUI | 18.3 | 51 | Running group/control | 3 weeks | IG/CG | $Log^v$ | Quality | 21 days | | ANOVA | ++ |
| | | | | Running group/control | 3 weeks | IG/CG | $Log^v$ | Insomnia | 21 days | | ANOVA | ++ |
| | | | | Running group/control | 3 weeks | IG/CG | EEG | 3-channel (Fp2-A1, C3-A2, C4-A1)) | 1 night (post) | 2,4 | ANOVA | ++ |
| **Lang C et al 2013* [48] | SUI | 18.0 | 56 | High/low PA | Last 2 weeks | Q | $Q^v$ | Quantity | Last 2 weeks | 1,3 | ANCOVA | + |
| | | | | High/low PA | Last 2 weeks | Q | $Q^v$ | Quality | Last 2 weeks | 1,3 | ANCOVA | 0 |
| | | | | High/low PA | Last 2 weeks | Q | $Q^v$ | Insomnia | Last 2 weeks | 1,3 | ANCOVA | + |
| | | | | High/low PA | Last 2 weeks | Q | EEG | One-channel (Fp2-A1) | 1 night | 1,3 | ANCOVA | 0/+ |
| | | | | High/low PA | 3 days | Acc | $Q^v$ | Quantity | Last 2 weeks | 1,3 | ANCOVA | 0/+ |
| | | | | High/low PA | 3 days | Acc | $Q^v$ | Quality | Last 2 weeks | 1,3 | ANCOVA | 0 |
| | | | | High/low PA | 3 days | Acc | $Q^v$ | Insomnia | Last 2 weeks | 1,3 | ANCOVA | 0 |
| | | | | High/low PA | 3 days | Acc | EEG | One-channel (Fp2-A1) | 1 night | 1,3 | ANCOVA | 0/+ |
| | | | | Level of PA | Last 2 weeks | Q | $Q^v$ | Quantity | Last 2 weeks | 1,3 | MRA | + |
| | | | | Level of PA | Last 2 weeks | Q | $Q^v$ | Quality | Last 2 weeks | 1,3 | MRA | + |
| | | | | Level of PA | Last 2 weeks | Q | $Q^v$ | Insomnia | Last 2 weeks | 1,3 | MRA | ++ |
| | | | | Level of PA | Last 2 weeks | Q | EEG | One-channel (Fp2-A1) | 1 night | 1,3 | MRA | + |
| | | | | Level of PA | 3 days | Acc | $Q^v$ | Quantity | Last 2 weeks | 1,3 | MRA | + |

**Table 4.1 continued**

| Author (year) | Population | | | Methods | | | | | | | | Results |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nat | Age | N | Assessing PA | | | Assessing sleep | | | Statistics | | |
| | | | | What is assessed | Time frame | How | How | What is assessed | Time frame | Design | Analysis | |
| | | | | Level of PA | 3 days | Acc | $Q^{v}$ | Quality | Last 2 weeks | 1,3 | MRA | + |
| | | | | Level of PA | 3 days | Acc | $Q^{v}$ | Insomnia | Last 2 weeks | 1,3 | MRA | ++ |
| | | | | Level of PA | 3 days | Acc | EEG | One-channel (Fp2-A1) | 1 night | 1,3 | MRA | + |
| *Lund HG et al 2010* [9] | USA | 17-24 | 1125 | Exercise (hours/week) | Habitual | Q | $Q^{v}$ | Optimal vs. poor sleep | Last month | 1,3 | MRA (B) | 0 |
| **Ortega FB et al 2010* [59] | ESP | 15.4 | 416 | Leisure/no leisure PA | Habitual | $Q^{1}$ | Q | TST: <8h / ≥8h | Habitual | 1,3 | LRA (OR) | + |
| | | | | Leisure/no leisure PA | Habitual | $Q^{1}$ | Q | Morning tiredness </≥4 days per week | Habitual | 1,3 | LRA (OR) | + |
| *Ortega FB et al 2011* [85] | EST, SWE | 15-16 | 678 | Moderate PA (min/day) | 4 days | Acc | Q | TST: <9h/≥9h, ≤10h/>10h | Habitual | 1,3 | ANOVA | 0 |
| | | | | Vigorous PA (min/day) | 4 days | Acc | Q | TST: <9h/≥9h, ≤10h/>10h | Habitual | 1,3 | ANOVA | 0 |
| | | | | MVPA (min/day) | 4 days | Acc | Q | TST: <9h/≥9h, ≤10h/>10h | Habitual | 1,3 | ANOVA | 0 |
| | | | | Average PA (counts/min) | 4 days | Acc | Q | TST: <9h/≥9h, ≤10h/>10h | Habitual | 1,3 | ANOVA | 0 |
| **Ronspies S et al 2011* [86] | USA | $7^{th}$-$8^{th}$ grd | 227 | Step count | 4 days | Ped | $Q^{1}$ | Quantity (TST) | Last 2 weeks | 1,3 | PPMCC | ++ |
| | | | | Activity time | 4 days | Ped | $Q^{1}$ | Quantity (TST) | Last 2 weeks | 1,3 | PPMCC | ++ |
| **Tynjälä J et al 1993* [60] | AUS, BEL, FIN,HUNI, SR, NORS, COS, WE, SUI, WAL | 15.5 | 8000 | Exercise frequency | Habitual/weekly | Q | Q | Quantity (TST) | Habitual week night | 1,3 | PPMCC | 0 |
| | | | | Exercise frequency | Habitual/weekly | Q | Q | Quality | Habitual week night | 1,3 | PPMCC | 0 |
| *Tynjälä J et al 1999* [33] | FIN | 15.9 | 1194 | Active/inactive (h/week + activity sport club) | Habitual | Q | Q | Good/bad sleep hygiene | Habitual | 1,3 | SEM | 0/++ |
| **Wydahl A 1991* [88] | NOR | 16-18 | 14 | Athletes/non-athletes | | Athl | Log | Average TST (h) | Last week | 1,3 | t-test | ++ |
| | | | | Athletes/non-athletes | | Athl | Log | Weekly sleep score | Last week | 1,3 | t-test | ++ |
| | | | | Athletes/non-athletes | | Log | Q | Weekly sleep score | 1*wk for 4 month | 1,3 | ANOVA | ++ |
| | | | | Athletes/non-athletes | | Log | Q | Weekly sleep score | 1*wk for 4 month | 2,4 | ANOVA | 0 |
| *Wydahl A 1991* [89] | NOR | 16-18 | 435 | Exercise frequency | Last week | Q | Q | General sleep score | Habitual | 1,3 | MRA | 0 |
| | | | | Exercise frequency | Last week | Q | Q | Last night sleep score | Last night | 1,3 | MRA | 0 |
| | | | | Exercise frequency | Yesterday | Q | Q | General sleep score | Habitual | 1,3 | MRA | 0 |
| | | | | Exercise frequency | yesterday | Q | Q | Last night sleep score | Last night | 1,3 | MRA | 0/++ |
| | | | | Exercise intensity | Last week | Q | Q | General sleep score | Habitual | 1,3 | MRA | 0 |
| | | | | Exercise intensity | Last week | Q | Q | Last night sleep score | Last night | 1,3 | MRA | 0 |
| | | | | Exercise intensity | Yesterday | Q | Q | General sleep score | Habitual | 1,3 | MRA | 0 |
| | | | | Exercise intensity | Yesterday | Q | Q | Last night sleep score | Last night | 1,3 | MRA | 0/++ |
| **Youngstedt SD et al 2003* [58] | USA | 22.9 | 43 | Average exercise duration (min/day) | 105 days | Log | Log | Quantity | 105 days | 2,3 | ρ (rho) | 0 |
| | | | | Most/least active day | Out of 105 days | Log | Log | Quantity | 105 days | 2,3 | t-test | 0/++ |
| | | | 11 | Most/least active day in top active third of sample | Out of 105 days | Log | Log | Quantity | 105 days | 2,3 | ρ (rho) | 0 |

*Notes:* * : included in meta-analyses. . Acc: exercise was assessed via accelerometer; Athl: athletes vs. non-athletes were compared; CG: control group; Design: 1: cross sectional study, 2: longitudinal study, 3: correlational study, 4: experimental study; EEG: sleep pattern was assessed via electroencephalogram at home; IG: intervention group; Log: assessed via log; MPA: moderate physical activity; PA: physical activity; Ped: exercise was assessed via pedometer; Stat.: statistical analysis; Time frame: describes whether the assessment of PA or sleep was retrospective or prospective, TST: total sleep time (h); Q: assessment via self-report with a questionnaire, $Q^{1}$: assessed via self-report questionnaire with a single item, $Q^{v}$: assessed via validated self-report questionnaire; VPA: vigorous physical activity;, 0 : no significant effects reported, + : small effect size (*d*), ++ : medium and large effect size (*d*).

Overall, even in this subsample, high and low subjective physical activity were assessed quite heterogeneously: athletes vs. non-athletes, leisure-time physical activity vs. no leisure-time PA, exercise vs. no exercise, high vs. low physical activity / moderate to vigorous physical activity (MVPA) / vigorous physical activity (VPA), running vs. no running group. Again, this might be a possible explanation for the moderate to high heterogeneity within this subsample analysis. In contrast, questions referring to subjective sleep were more comparable to one another, as only studies representing qualitative ($n$ = 4) or only quantitative ($n$ = 2) aspects of sleep were included.

*Relationship between subjective physical activity and objective sleep*

Figure 4.3 shows that the second largest subgroup analysis included four studies of the twelve, indicating that objective assessments have been used more frequently for sleep than for PA. However, the number of participants within this subgroup is considerably smaller, including only 169 adolescents, with a median sample size of 44.5 (range 24 – 56) per study.

The meta-analysis yielded a large overall effect size of $d$ = 0.907 ($z$ = 2.217; $p$ < .05; CI [0.105; 1.708]; $I^2$ = 35.41%) indicating that higher subjective physical activity is associated with better objective sleep. The $I^2$-index indicates a low to moderate heterogeneity, which may due to the fact that all studies computed objective sleep efficiency via sleep-EEG, with which participants slept at home in their normal environment. However, further investigation revealed that these studies were conducted by the same research group. Interestingly, studies assessing sleep via PSG in a sleep lab and via accelerometers are absent from this population and field of research.

*Relationship between objective physical activity and subjective sleep*

As shown in Figure 4.3, the relationship between objective physical activity and subjective sleep was assessed in two studies, indicating that objective methods are still rare with this population and in this field of research. The subsample analysis includes 98 adolescents, with a median sample size of 49 (range 42 – 56) per study. Both studies used accelerometers (wrist/hip actigraphy). The devices were worn on three to seven consecutive days.

The meta-analysis yielded a medium overall effect size of $d$ = 0.541 ($z$ = 1.291; $p$ = 0.197; CI [-0.281; 1.364]; $I^2$ = 0.00%), indicating that higher objective physical activity is associated with better subjective sleep. However, this effect was not significant, which is attributable both to the low sample size and the fact that the outcomes of the two studies were highly divergent. The $I^2$-index indicates no heterogeneity, which is most likely the result of the small sample sizes within this subgroup.

| Study | N | cntry | age | PA assessment: how | PA assessment: What is assessed? | Sleep assessment: how | Sleep assessment: What is assessed? | Meta-analytic calculation: *d* | *SE* | *Z* | *p* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Objective PA and objective sleep** | | | | | | | | | | | |
| *Gerber M et al 2014* [92] | 42 | SUI | 21.2 | Acc | High vs. low PA | EEG | SE % | 0.400 | 0.432 | 0.925 | 0.355 |
| *Lang C et al 2013* [48] | 56 | SUI | 18.0 | Acc | High vs. low PA | EEG | SE % | 1,608 | 0,383 | 4,193 | 0.000 |
| **Overall** ($I^2$ = 0.00%, p = 1.000) | | | | | | | | **1.021** | **0.604** | **1.680** | **0.091** |
| **Objective PA and subjective sleep** | | | | | | | | | | | |
| *Gerber M et al 2014* [92] | 42 | SUI | 21.2 | Acc | High vs. low PA | Q | quality | 0.958 | 0.327 | 2.928 | 0.003 |
| *Lang C et al 2013* [48] | 56 | SUI | 18.0 | Acc | High vs. low PA | Q | quality | 0.119 | 0.355 | 0.355 | 0.723 |
| **Overall** ($I^2$ = 0.05%, p = 0.368) | | | | | | | | **0.541** | **0.419** | **1.291** | **0.197** |
| **Subjective PA and objective sleep** | | | | | | | | | | | |
| *Brand S et al 2010* [7] | 38 | SUI | 18.6 | Q | High vs. Low VPA | EEG | SE % | 0.123 | 0.327 | 0.378 | 0.706 |
| *Brand S et al 2010* [46] | 24 | SUI | 16.0 | Athl | Athletes vs. non-athletes | EEG | SE% | 2.588 | 0.553 | 4.677 | 0.000 |
| *Kalak N et al 2012* [18] | 51 | SUI | 18.3 | Athl | Running- vs. no running-group | EEG | SE % | 0.510 | 0.285 | 1.791 | 0.073 |
| *Lang C et al 2013* [48] | 56 | SUI | 18.0 | Q | High vs. Low PA | EEG | SE % | 0.822 | 0.352 | 2.335 | 0.020 |
| **Overall** ($I^2$ = 35.41%, p = 0.164) | | | | | | | | **0.907** | **0.409** | **2.217** | **0.027** |
| **Subjective PA and subjective sleep** | | | | | | | | | | | |
| Armstrong & Oomen-Early 2009 | 227 | USA | 19.9 | Athl | Athletes vs. non-athletes | Q | quality | 0.487 | 0.135 | 3.611 | 0.000 |
| *Brand S et al 2009* [87] | 70 | SUI | 15.4 | Athl | Athletes vs. non-athletes | Log | quality | 0.798 | 0.248 | 3.211 | 0.001 |
| *Brand S et al 2010* [7] | 38 | SUI | 18.6 | Q | High vs. low VPA | Q | Insomnia | 0.612 | 0.477 | 1.285 | 0.199 |
| *Brand S et al 2010* [17] | 434 | SUI | 17.2 | Athl | Athletes vs. non-athletes | Log | quality | 0.487 | 0.161 | 3.024 | 0.002 |
| *Brand S et al 2010* [46] | 24 | SUI | 16.0 | Athl | Athletes vs. non-athletes | Log | quality | 3.586 | 0.659 | 5.440 | 0.000 |
| Gerber et al 2010 [91] | 862 | SUI | 24.7 | Q | High vs. low PA | Q | quality | 0.072 | 0.077 | 0.939 | 0.348 |
| *Holmberg LI et al 2008* [37] | 1325 | SWE | 17.3 | Q | Exercise vs. no exercise | Q | Good vs. bad sleepers | 0.428 | 0.136 | 3.152 | 0.002 |
| *Kalak N et al 2012* [18] | 51 | SUI | 18.3 | Athl | Running- vs. no running-group | Log | quality/insomnia | 0.835 | 0.293 | 2.854 | 0.004 |
| *Lang C et al 2013* [48] | 56 | SUI | 18.0 | Q | High vs. Low PA | Q | quality | 1.196 | 0.370 | 3.232 | 0.001 |
| *Wydahl A 1991* [88] | 14 | NOR | 16-18 | Athl | Athletes vs. non-athletes | Log | quality | 8.667 | 1.725 | 5.025 | 0.000 |
| *Youngstedt SD et al 2003* [58] | 43 | USA | 22.9 | Log | Most active vs. least active day | Log | quality | 1.697 | 0.296 | 5.729 | 0.000 |
| **Overall** ($I^2$ = 70.49%, p = 0.000) | | | | | | | | **0.943** | **0.197** | **4.786** | **0.000** |

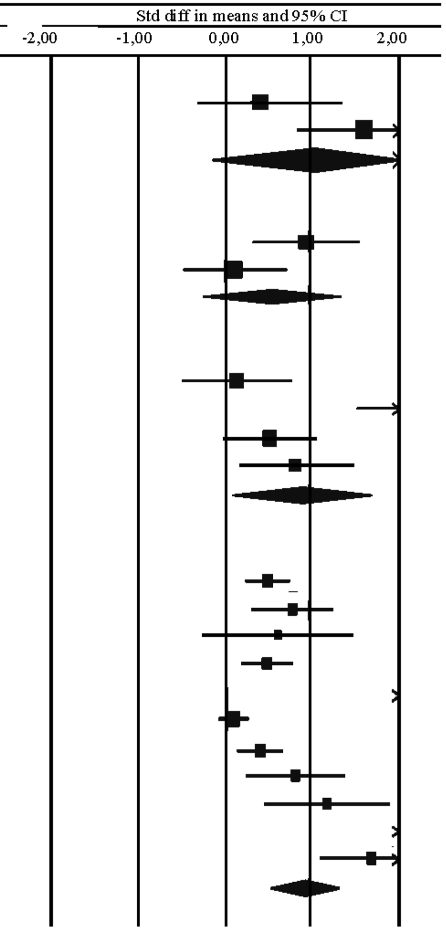


**Figure 4.3. Forest plot presenting the subgroup meta-analysis for the effect of physical activity on sleep (all the meta-analytic calculations were done using a random-effect meta-analytic model).**
Abbreviations: Acc: objective assessment of PA via accelerometer, Athl: subjective grouping of participants according to being an athlete or not, CI: confidence interval, cntry: country, I-squared: statistical index of heterogeneity, d: standard difference in means, EEG: objective assessment of sleep via electroencephalogram at home, Log: subjective assessment via daily log/diary, MPA: moderate PA, MVPA: moderate and vigorous PA, *p*: p-value, PA: physical activity, Ped: objective assessment of PA via pedometer, Q: subjective assessment via questionnaire, *SE*: standard error, SE%: sleep efficiency, TST: total sleep time, VPA: vigorous PA,. *z*: z-value.

*Relationship between objective physical activity and objective sleep*

Figure 4.3 also gives the fourth subgroup analysis examining the relationship between objective physical activity and objective sleep. Such analyses were again only performed in two studies, indicating that objective methods of data assessment are still rarely used with this population and in this field of research. The subsample analysis is based on 98 adolescents, with a mean sample size of 49 (range 42 – 56) per study.

The meta-analysis yielded a large overall effect size of $d$ = 1.021 ($z$ = 1.680; $p$ = .091; CI [-0.163; 2.204]; $I^2$ = 0.00%) indicating that higher objective physical activity is associated with better objective sleep. The $I^2$-index indicates no heterogeneity, as there are only two studies within this subgroup.

*Comparison of effect sizes across subgroups*

The largest overall effect size, supporting a positive relationship between physical activity and sleep, was found for the relationship between *objective physical activity and objective sleep* ($d$ = 1.021; $z$ = 1.680; $p$ = .091; CI [0.163; 2.204]; $I^2$ = 0.00%), followed by *subjective physical activity and subjective sleep* $d$ = 0.983 ($z$ = 4.826; p < .001; CI [0.584; 1.382]; $I^2$ = 71.04%), and then *subjective physical activity and objective sleep* ($d$ = 0.907 ($z$ = 2.217; $p$ <.05; CI [0.105; 1.708]; $I^2$ = 35.41%), with *objective physical activity and subjective sleep* having the smallest ($d$ = 0.541 ($z$ = 1.291; $p$ = 0.197; CI [-0.281; 1.364]; $I^2$ = 0.00%). No study showed a negative effect size, while most effect sizes (17 from 19) ranged from small to large, but this might also be a result of publication bias.

A closer inspection of the studies that included more than one different measurement method [7,46,48,92] revealed, in three cases, larger effect sizes for the relationship between subjective physical activity and subjective sleep. Moreover, Lang et al. [48] assessed both physical activity and sleep objectively and subjectively and effect sizes were considerably larger among subgroups in which subjective or objective methods were used exclusively. However, as the true value of the relationship between physical activity and sleep is not known, and due to the fact that only one study [48] has included both subjective and objective assessments of physical activity and sleep, it seems premature to argue in favor of one or other methodological approach in future studies. It might however make sense in future analysis to apply a multi-modal assessment (i.e., subjective and objective) of both sleep and PA, as both subjective and objective assessments provide reliable data.

*Publication bias*

In the present meta-analysis, a funnel plot could only be conducted for subgroup analysis with at least three studies, that is in two of the four subgroup analyses, those involving the relationship between *subjective physical activity and subjective sleep* (11 studies), and *subjective physical activity and objective sleep* (4 studies). The funnel plots are shown in Figure 4.4. In the first analysis, the funnel plot showed a high risk of publication bias in that small-scale studies with small and negative study effects were missing. Larger studies appear to be rather symmetrically clustered around the mean effect size, showing positive and negative study effects by visual inspection. Even without the outlier [88], the high risk of bias remains stable. Larger and well powered studies show rather small effects.

In the second analysis, the sample of the studies is quite similar. However, the funnel plot represents a more balanced distribution around the mean effect size, although studies with positive effect sizes seem to be more frequently published. Studies with low or negative effect sizes were not present. Nevertheless, due to the low number of data points (<10), it is not possible to draw reliable conclusions on the presence of publication bias [96]. It is also important to note that funnel plot asymmetry could be due to factors other than publication bias [97], such as differences in methodological quality or heterogeneity [96]. In support of this, Rosenthal`s fail-safe N suggests robustness for the relationship between *subjective physical activity and subjective sleep* (fail-safe *N* = 356), *subjective physical activity and subjective sleep without outlier* (fail-safe *N* = 265), *subjective physical activity and objective sleep* (fail-safe *N* = 18), and for the overall meta-analysis (fail-safe *N* = 249).

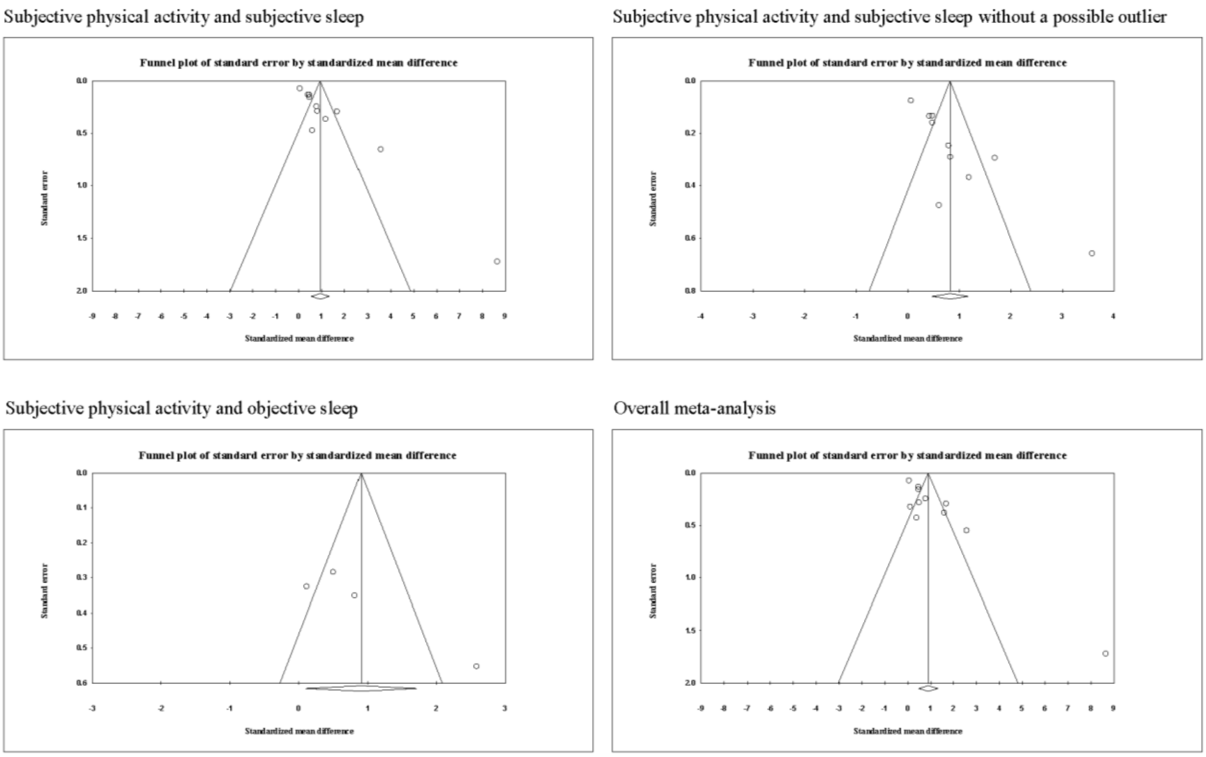


**Figure 4.4. Funnel Plots of publication bias**
In the present meta-analysis, a funnel plot could only be conducted for subgroup analysis with at least three studies, that is in two of the four subgroup analyses: *subjective physical activity and subjective sleep* (11 studies), and *subjective physical activity and objective sleep* (4 studies).

## DISCUSSION

This is the first systematic review and meta-analysis to focus upon methodological issues in assessing the relationship between regular physical activity and nocturnal sleep among healthy adolescents. As studies have typically used various assessment methods, this systematic review and meta-analysis aimed at summarizing the currently available measurement tools and their application within the adolescent population. To this end, 21 studies with a total of 16,549 participants in the age range 14-24 years were identified. Consistent with previous reviews of research on adults and adolescents [22,23,28,67], the results indicate that adolescents with higher subjective and objective physical activity levels are more likely to experience good nocturnal sleep, both subjectively and objectively. Generally, these findings remained observable even after controlling for possible confounders such as psychological functioning [7,17]. However, our particular focus was whether the strength of this relationship varies with the method of assessment.

The detailed examination of the assessment tools employed in the reviewed studies showed that current discussions about the relative validity of subjective and objective tools that have taken place in the separate fields of sleep research [2,39,42] and physical activity research [56,61,64] have done so largely in isolation from one another. Few of the studies reviewed have attempted to quantify physical activity or identify groups of high and low physical activity levels using accepted metrics. Likewise, clinical diagnoses of sleep disorders have rarely been applied, nor have questions been included addressing accepted criteria for sleep disorders. Moreover, some studies have treated sleep duration as an indicator of sleep quality, where this latter refers to an individual's appraisal of how sleep is experienced, including feelings of being restored. However, Dewald et al. [1] argue that sleep duration and sleep quality need to be regarded as two separate sleep domains and among adolescents correlations between the two are found to be low or non-significant [98]. This might explain why the relationship between physical activity and subjective sleep duration, and physical activity and subjective sleep quality, varies considerably across the studies reviewed. Three quarters of all studies examining the relationship between physical activity and subjective sleep duration found no significant relationship. This finding corroborates previous results, in which the association of health behavior is stronger with subjective sleep quality than with subjective sleep duration [4,98]. Therefore, the choice to focus on either quantitative or qualitative aspects of physical activity and sleep may be an important consideration when developing a questionnaire. Moreover, a recent validation study examining two different question formats (one general question versus two questions asking separately about weekday and weekend sleep duration) with 1,040 adults (aged 18 and older) demonstrated that question wording can affect reported sleep duration in complicated ways. It thus appears difficult to compare studies using different question formats [98]. Generally, many studies lack sufficient analysis of possible confounders such as age [85], gender [48], daylight length [85,88] or mental health [39]. Thus, it was impossible to perform statistical analyses of all subgroups among the studies included in the present meta-analysis while controlling for the major confounders such as gender, psychological functioning and mental and physical health status.

In any event, the use of self-reports, such as questionnaires, logs and surveys were the most commonly used methods in assessing the relationship between physical activity and sleep. Although self-reports are generally seen as useful for gaining insight in large scale studies, objective measures are believed to offer more robust and precise estimates [61], solving problems of response bias as well as over- and under estimation [61,99]. In line with this view, the trend has been toward use of objective methods to assess the relationship between physical activity and sleep. However, only a few studies have relied exclusively upon objective measures. There was an observable trend toward assessment of one variable via an objective measure while assessing the other subjectively. Nevertheless, approaches mixing assessment methods in this way do not appear to produce larger positive effect sizes. The largest emerged when either objective or subjective assessments were used for both sleep and PA, an observation that corroborates the results of a previous study [48]. Notably this is also not necessarily consistent with the possibility that subjective assessments of both could inflate the strength of the relationship because of shared biases. Gerber et al. [91] conclude from their findings that the association between physical activity and sleep might be a rather mental affair. In other words, physical activity may lead to increased psychological well-being; as a result, one may also be subjectively more satisfied with one`s sleep. Also, when one feels sleep-deprived, physical activity might be one of the first behaviors abandoned [29]. Research has suggested that a low level of physical activity is one of the most significant correlates of daytime sleepiness [29].

It was surprising that none of the studies used accelerometers to assess the relationship between physical activity and sleep, as both can be measured using the same instrument. Weiss et al. [42] were able to show with 30 adolescents that data on sleep-wake patterns from three different devices were well correlated with PSG measures. Although this association was poorer for measures of sleep efficiency, they point out that use of actigraphy devices would accelerate the collection of more comprehensive physiological data while minimizing the costs and participant burden.

Above all, the selection of appropriate measurement tools must take into account several factors unique to the adolescent population. To overcome some of the limitations identified above, Table 4.3 summarizes considerations for researchers planning to conduct future studies in this field of research. However, one should note that the choice of assessment method remains a trade-off between feasibility and validity and all aspects should be thoroughly considered before use in a study. Especially at a time of continual technological and scientific progress, this choice is time-dependent, and has to be balanced against the resources available at the beginning of a study.

Finally, there are several limitations to this meta-analysis that should be noted. Firstly, the visual inspection of the funnel plots might speak for a publication bias showing in particular that small studies with low or negative effects sizes are missing. However, Rosenthal`s fail-safe values suggests there could be other reasons for this asymmetry.

Secondly, only one study assessed both subjective and objective measures of physical activity and sleep within the same sample. However, to make confident statements about whether this relationship depends on the method of data collection, more studies are needed. Thus, our third aim, to assess whether methodology is associated with the outcomes, could not be fully answered as meaningful moderator analysis requires more studies to address this issue. Thirdly, almost all studies were cross-sectional in design, and this precludes any causal inferences about the link between physical activity and sleep. However, there is evidence elsewhere for a causal influence of physical activity on sleep. Kalak et al. [18] found that a three-week intervention involving morning runs impacted on sleep among healthy adolescents both subjectively and objectively. Fourth, in carrying out the meta-analysis, we were not able to control for other confounding variables, such as light exposure. Lastly, the study sample was based on healthy adolescents. Thus, one may argue that the results could be limited by ceiling-floor effects, and that even stronger relationships might be apparent among adolescents with mental health problems.

**Table 4.2**
Considerations for researchers interested in assessing the relationship between physical activity (PA) and sleep among adolescents.

**Assessing physical activity subjectively**

- □ Use validated questionnaires, even for population surveillance. Three instruments were identified as potentially most suitable for use in epidemiological studies: PAQ-A [100], YRBS [101], Teen Health Survey (itself a shortened 2-item modification of the YRBS) [102]. In turn, SHAPES [103] and IPAQ-A [56] assess PA elaborately, and are therefore recommended for the use in experimental studies. For further information see Biddle et al. [70], and Ottevaere et al. [56].
- □ Identify PA patterns (frequency, duration, intensity) as well as activity-related energy expenditure (METs).
- □ Do not use adult-based classifications of moderate (3-5.9 METs) and vigorous (>=6METs) PA, or rely on the compendium of physical activities [104,105], as it likely results in an overestimation of PA in adolescents. Currently there are efforts being made to develop a compendium of energy expenditure for youth [106].
- □ When analyzing data, consider that subjective PA is generally overestimated when compared with actigraphy and heart rate monitoring. VPA tends to be overestimated; MPA is likely underestimated (which is more sporadic and therefore less quantifiable) [107], especially among physically inactive adolescents. Additionally, an activity episode is often recalled as one bout (e.g. ball game) instead of multiple bouts during one activity.
- □ When forming groups of different PA levels, you may consider accepted recommendations of PA, such as from the Centers for disease control and prevention (CDC) or the American college of sports medicine (ACSM). Consider that using different standards for categorization may impact greatly on the number of adolescents classified as sufficiently versus insufficiently active.
- □ If you compare athletes with non-athletes, you should consider the overtraining syndrome, which may negatively affect sleep pattern [28].Consider that non-athletes might not necessarily be physically inactive.
- □ Consider controlling for gender differences, as male adolescents generally tend to overestimate their PA levels and female adolescents are less physically active compared to males [48].
- □ You may ask questions about the setting in which the PA takes place, e.g. indoor or outdoor, because chronic exposure to bright light can enhance sleep [55,108].
- □ Consider that sedentary behavior (e.g. TV viewing, video game playing, computer use, and reading) impacts health, independent of other factors, including body weight, diet, and PA [109].

**Assessing physical activity objectively**

- □ When assessing objective PA among large scale studies, you may prefer the use of pedometers or accelerometers; due to their relatively low costs and low participant burden [61,110].
- □ It is recommendable to measure PA during daily life, over periods long enough to be representative of the habitual activity level. Consider that adolescents have higher day-to-day variability than children with regard to MVPA [111]; and protocol compliance tends to decrease with time elapsed. Corder et al. [55] suggest at least 4 full days (not necessarily consecutive), including one weekend day.
- □ Pedometer output should be expressed as steps per day without further inference of distance or energy expenditure, as this may produce an unacceptably high level of uncertainty [55].
- □ Consider that accelerometers require calibration before use [112].
- □ Decide whether to discount or scale the first day of accelerometer/pedometer recording, because pedometers displaying the number of steps may alter behavior. Similarly, accelerometer counts are 3% higher during the first day of measurement than subsequent days [55].
- □ Consider additionally administering a PA log, as accelerometers are ill-equipped to capture and assess cycling, swimming, or arm-intensive activities and often need to be removed for contact sports, including volleyball [61].

- □ Bear in mind that the selection of specific cut-points can drastically affect the amount of PA categorized as moderate versus vigorous according to PA guidelines. Several age-specific activity thresholds have been suggested for adolescents with different accelerometer cut points proposed [113-115].
- □ Consider that adolescents may be less willing to wear an activity monitor if it clashes with their idea of style and fashion [55]. For further information on the use of accelerometers in adolescents see de Vries et al.[116], Reilly et al. [117], Rowlands [118].
- □ Keep in mind that, except for heart rate monitors, different brands of wearable monitors have no uniformity in output units [64]. Moreover, many commercially available activity trackers are insufficiently validated.
- □ Consider that heart rate monitor data are influenced by age, body size, proportion of muscle mass utilized, emotional stress and cardiovascular fitness on the heart rate response. Additionally, the heart rate response lags behind changes in movement and thus tends to remain elevated after movement [61].
- □ While accelerometers measure moving units, DLW is a method to measures 24h total energy expenditure (TEE), which i.e., depends on a subject’s weight. Because the largest compartment of the daily energy consumption is resting energy expenditure (REE), you need to adjust data for resting metabolic rate and thermic effect of food [61]. You may capture this with indirect calorimetry and then calculate the activity energy expenditure (AEE) from the difference between TEE and REE. However, consider that DLW is highly costly; although the price per sample varies, you should expect about 250 US$ per sample (not including analysis in a commercial laboratory). For further information on methodological aspects of assessment of energy expenditure in children and adolescents see the review of Müller & Bosy-Westphal [119].
- □ Decide whether it might be more suitable for your purpose to use multiple sensor systems, which combine one or more physiological measures with movement sensing. For more information on use in adolescents see Corder et al. [120,121]; and Zakeri et al. [122].
- □ Consider that certain features of the laboratory environment (e.g., boredom on a treadmill) could inhibit usual beneficial effects of exercise on sleep [67].

**Assessing sleep subjectively**

- □ Consider that retrospective recalls of sleep (questionnaire) are generally less accurate than prospective sleep assessments (sleep log).
- □ The two most common self-report symptom questionnaires are the ISI [94], a 7-item self-report questionnaire and the PSQI [93], a more global measure of sleep disturbances.
- □ There are some validated questionnaires for children and adolescents with sleep problems: The PSQ is a 67 item instrument which has been validated in a wider age range, 4 to 18 years [123]. It covers a wide range of sleep problems in children and has a sleepiness subscale, and a sleep related breathing disorder subscale (which is the only non-PSG tool found to be useful in identifying obstructive sleep apnea). The CHSQ [124] has been used in clinical research and is applicable to screening as well. The CHSQ is a 35 item, 3-page questionnaire validated for 4 to 10 year old children, but often used in children from 2 to 18 years.
- □ If you are planning on designing your own instrument, see Spruyt & Gozal [125], who provide information on the theoretical and pragmatic processes required for instrument design and development, i.e., how any questionnaire, inventory, log, or diary should be created and evaluated. They also provide illustrative examples to further underline the potential pitfalls that are inherently embedded in every step of tool development.
- □ When assessing adolescents with mental health problems (e.g., insomnia, depression) bear in mind that subjective complaints are the primary means of defining insomnia, and subjective feelings of improvement remain the primary means of determining improvement clinically. Therefore, adolescents diagnosed with primary insomnia often report worse sleep than can be verified with objective sleep recordings [21,126,127].
- □ Generally, female adolescents report higher sleep complaints than males.
- □ Consider that the menstrual cycle can influence sleep [128].

- □ Be aware that chronic exposure to bright light can enhance sleep. Thus, it is important to carefully consider the setting in which the PA takes place, e.g. inside or outside [55,108].
- □ Reflect on whether you need questions for weekend-nights, as there is a greater variability between weekend-nights as compared to school-nights. Thus, such a survey query may provide some difficulties, as adolescents have to give a one-value estimate to a more variable phenomenon. On the other hand, weekend nights may better reflect adolescent`s sleep patterns because they take into account more information [129].
- □ When analyzing self-reports consider that most people are not always aware of WASO or when they actually fell asleep. Especially adolescents tend to underestimate TST and WASO and overestimate SOL when compared to PSG studies [40,41].
- □ Consider that some instruments provide clinical cut-off scores [130], whereas others do not. Using clinical cut-off score might help to interpret the meaningfulness of the associations between PA and sleep.

**Assessing sleep objectively**

- □ Decide whether your sample is appropriate for objective or subjective measures of sleep: Adolescents who report fair or poor health actually have no significant correlation between measured and reported sleep, and report on average shorter sleep hours than those with better self-rated health [39]. In fact, the standards in the field dictate that PSG should not be used in routine assessment for insomnia [131].
- □ Be aware that the sleep-EEG record on an assessment-night depends strongly on the adolescent`s history prior to recording (e.g., sleep schedule in the previous days, drugs).
- □ Consider that assessing sleep patterns in a laboratory disrupts sleep routine. In turn, actigraphy does not perturb normal sleep habit as there appears to be no "first-night effect" [32].
- □ Keep in mind that sleep-EEG devices measure the sleep pattern of one night and sleep is sensitive to many factors. Many more days of objective assessment might be needed to delineate the effects of PA on objective sleep-EEG [67].
- □ Actigraphy allows for collecting information about sleep patterns over an extended period of time (24h a day, 1-2 weeks) in the adolescent`s typical sleep environment. Consider that only few instruments are sufficiently validated [132].
- □ When aiming to collect 5 nights of actigraphy, you should record for at least 1 full week. Reliability estimates for values aggregated over any 5 nights were adequate for sleep start time, wake minutes, and sleep efficiency. Measures of sleep minutes and sleep period were less reliable and may require 7 or more nights for estimates of stable individual differences. Reliability for 1- or 2-night aggregates was poor for all measures [43].
- □ Consider that accelerometers can measure both sleep and activity, and this may accelerate the collection of objective data while minimizing costs and participant burden [42].
- □ When analyzing sleep data from accelerometers, consider that there is reduced wake-time sensitivity: sedentary behavior or non-wearing periods may be registered as sleep time. Thus, the application of a sleep-diary may be used.
- □ Consider that applying PSG requires monitoring in a sleep laboratory. Certain features of the laboratory environment (e.g., invasive sleep recording) could inhibit usual beneficial effects of exercise on sleep [67]. Due to the "first-night effect" adolescents need to come to the laboratory at least twice.
- □ You need sleep researchers or trained staff to analyze objective sleep data from actigraphy, sleep-EEG or PSG.

*Notes.* CHSQ: Children's Sleep Habits Questionnaire, DLW: doubly labeled water, ESS: Epworth sleepiness scale, ISI: Insomnia severity index, IPAQ-A: International Physical Activity Questionnaire for Adolescents, MET (Metabolic equivalent of task), MPA: moderate physical activity, MVPA: moderate-to-vigorous physical activity, PAQ-A: Physical activity questionnaire for adolescents, PSQ: Pediatric sleep questionnaire, PSQI: Pittsburgh sleep quality index, SHAPES: School health action, planning and evaluation system physical activity questionnaire, VPA: vigorous physical activity, YRBS: Youth risk behavior surveillance survey.

## CONCLUSIONS

This is the first systematic-review and meta-analysis that sheds light on methodological issues pertaining to the examination of the relationship between physical activity and sleep among adolescents. This review shows that there is a multitude of instruments to assess both physical activity and sleep, each with its own advantages and drawbacks. Therefore, no gold standard for measuring the relationship between regular physical activity and sleep currently exists although several aspects should be considered in order to guarantee trustworthy data. Notwithstanding the variety of methodological approaches employed in assessing physical activity and sleep, the present meta-analysis indicated medium to large effect sizes across all subgroup analyses. Importantly, none of the studies reviewed showed that higher levels of physical activity impact negatively on adolescents` sleep.

### PRACTICE POINTS

1. Adolescents with higher subjective and objective physical activitylevels are more likely to experience a good night's sleep subjectively and objectively.
2. The majority of the studies were cross-sectional in design and used subjective measures. Few studies have used objective procedures to measure sleep. None of the studies used accelerometers, although both physical activity and sleep can be assessed using this instrument.
3. Sleep and were often assessed using instruments with limited or unknown reliability and validity. Knowledge of current best practice in assessing sleep and physical activity in each research field has rarely been applied.
4. Studies relating physical activity to sleep where both measures were assessed either subjectively or objectively identified larger effect sizes, than those combining subjective with objective measures.
5. Only one study has used both subjective and objective measures to assess the relationship between physical activity and sleep, with the objective of establishing which is the better methodological approach. Thus, a conclusion on the possible association with the chosen assessment tools remains impossible.
6. The choice between assessment methods is necessarily a trade-off between feasibility and validity and all aspects should be thoroughly considered in making the choice. Technological advances and the development of new assessment tools are continually shifting the balance between feasibility and validity.

**RESEARCH AGENDA**

In the future, researchers should consider the following points:

1. Use well validated instruments when assessing physical activity and sleep subjectively.
2. Establish standardized research protocols, for example to control for potential confounding variables, especially when conducting epidemiological studies, and to allow more thorough comparison of data and results from different studies.
3. Contribute to current research on an adolescent-based energy expenditure compendium of physical activity values so that recall of physical activity can be more precisely converted into an estimation of calorie use at different stages - early, middle and late - of adolescence.
4. Establish standardized and comparable cut-off values for accelerometers so that sedentary behavior, light moderate and vigorous physical activity levels can be distinguished in adolescents.
5. Compare different accelerometers as measures of both physical activity and sleep among adolescents and identify the best options for this combined purpose.
6. Conduct further studies that apply both subjective and objective measures for the assessment of physical activity and sleep within the same sample.
7. Conduct further meta-analyses, which place a special focus on the following possible methodological confounds: e.g., athletes vs. non-athletes, high vs. low moderate/vigorous physical activity, exercise vs. non-exercise days, sleep duration vs. sleep quality, cross-sectional vs. pre-post-invention studies, combination of subjective and objective assessment tools.

## SUPPLEMENTARY ONLINE MATERIAL

### Table 4.3. Summary of publications included in the systematic review.

| Author (year) | Sample Description | Measurements: Assessing Sleep | | Measurements: Assessing PA | | Statistics | Results and discussion |
|---|---|---|---|---|---|---|---|
| | $N_{anazlyzed}$ / Age / Population | Self-report | objective | Self-report | objective | | |
| *Alricsson M et al 2008* [34] | N=466 (m 185; f 281)<br>16.2 y (± 0.8)<br>Australian state high school students from two high school communities in Queensland. Grades 10-12. | Questionnaire<br>Sleep well, wake up at night (toilet), difficulty to fall back asleep, morning and daytime tiredness, bed and morning wake time. | ------------- | Questionnaire<br>How often PA is performed at a low, medium, high level of effort)<br>Type of PA/sport and frequency of activities during the last 6 mth. | ------------- | $\chi^2$-test | **No association of reported exercise and sleep.**<br>No difference in sleep variables was observed in groups with different degrees of PA. Only daytime sleepiness was answered significantly more often (p<.01) among participants who reported low or no PA than those with medium or high PA. |
| *Armstrong S et al 2009* [36] | N=227 (m 91; f 136),<br>19.9 y (±1.33),<br>Full time undergrad students at a small, private, liberal arts college in the South US (athletes n=104; non-athletes n=123) | Questionnaire:<br>Days of rested sleep/wk | ------------ | Questionnaire:<br>Days of aerobic exercise/wk and days of strength training/wk | ------------ | ANOVA | **Positive association of being a collegiate athlete and reported days of rested sleep.**<br>When comparing collegiate athletes and non-athletes, analysis revealed a significant main effect in that athletes displayed more d/wk of aerobic ex. F=101.61, strength training F=58.98, and had more rested sleep nights per wk F=12.15, *d**=0.49 [S] than non-athletes (all df.=3.223; all p<.001). |
| *Brand S et al 2009* [87] | N=70 (m 70; f 0)<br>15.4 y (±0.86)<br>36 healthy male chronic and intense football players, recruited from a Swiss football club in Basel. CG: 34 healthy males, matching age, school and intellectual skills. No regular exercise. | Sleep log:<br>Based on the PSQI (Buysse et al. 1989), German adaption (Backhaus & Riemann 1996). Morning-/evening ratings on 7 consecutive days. | ------------- | Questionnaire:<br>Athletes (mean hours of ex. 12.69; SD=2.05) and non-Athletes (M=1.56; SD=1.02) | ------------- | ANOVA | **Positive association of being a football player and reported sleep.**<br>Compared to controls, football players reported better scores for mood in the morning F=10.35, *d**=0.77 [M], and evening F=21.35, *d**=1.11 [L], sleep quality F=18.64, *d**=1.03 [L], and restoring sleep F=12.77, *d**=0.85 [L], shortened sleep latency F=44.49, *d**=1.60 [L], and a lower number of awakenings after sleep onset F=21.81, *d**=1.12 [L], (all df.=1.67; all p<.01). This pattern was shown for both school and off-school nights. |
| *Brand S et al 2010* [7] | N=38 (m 20; f18)<br>17 high exercisers; 21 low<br>18.6 y (±0.29)<br>Adolescents from a high school in the North-Western part of Switzerland. Only participants without psychiatric disorder were enrolled in the study (Ackeneil et al. 1999) | Questionnaire:<br>Insomnia Severity Index (ISI; Bastien et al. 2001) | Sleep-EEG:<br>One-channel EEG device (Fp2-A1; electro-myogram; Som-nowatch, Ran-dersacker, GER). Sleep registration during a week night following a day w/o ex. | Questionnaire:<br>Within the last week, for how many hours do you do vigorous exercise? To distinguish between high/low exercisers, the cut off point was set at 3.5 h | ------------ | ANOVAs<br>MLR | **Positive association of reported exercise with objective sleep, but not with reported sleep.**<br>Compared to low exercisers, high exercisers had longer TST, *d**=0.99 [L], higher SE, *d**=1.06 [L], more stage shifts, *d**=1.10 [L], less stage 2, *d**=1.05 [L], and light sleep, *d*=0.74 [M], increased stage 4, *d**=1.46 [L], and SWS, *d**=1.49 [L], and decreased REM-sleep, *d**=0.90 [L]. No sign. group differences were observed for subjective sleep (ISI). Decreased weekly exercise predicted longer SOL. WASO and SWS was neg. predicted by weekly ex. duration. Decreased REM-sleep was predicted pos. by weekly ex.<br>Duration, r=0.31, p<.05, *d**=.0.65 [M], and increased SWS, r=0.88, p=0.001. *d**=3.71 [L], decreased light sleep, r =-0.31, *d**=-0.65 [M], and fewer WASO; r=-0.39, p<.05, *d**=-0.85 [L]. |
| *Brand S et al 2010* [17] | N=434 (m 156; f 278)<br>17.2 y (±0.5)<br>Adolescents athletes (n=258) were recruited from Swiss Olympic Classes in the German speaking part of Switzerland. Controls (n=176) were recruited in the cantons of Basel. | Sleep log<br>Based on the PSQI (Buysse et al. 1989), German adaption (Backhaus & Riemann 1996). Morning-/evening ratings on 7 consecutive days. | ------------- | Exercise log<br>7-day log asking about vigorous exercise (h) from participation in PE and sport. Scores of 7 consecutive days were summed | ------------- | ANOVAs<br>MLR | **Positive association of reported sleep with being an athlete, but not with reported vigorous exercise (h/wk).**<br>Compared with controls, athletes had higher scores for self-reported sleep quality, *d**=0.40 [S], restoring sleep, *d**=0.40 [S], shorter SOL, *d**=0.52 [M], fewer WASO, *d**=0.41 [S], and lower tiredness during the day, *d**=0.82 [L]. No sign. group differences were found for TST. Sleep quality was predicted by being an athlete (*d**=0.76 [M]) and tiredness during the day (*d**=0.42 [S]) by being a participant of the control group. Total hours of self-reported vigorous ex. per wk had no predictive value. Male low exercisers were at increased risk for poor sleep. |
| *Brand S et al 2010* [46] | N=24 (m 24; f 0)<br>16.0 y (±1.4)<br>12 male vigorous football playsers (n=12) were recruited from the male junior section of the Concordia Football Club, Basel, German speaking part of Switzerland. Controls (n=12) were recruited from the same school classes. | Sleep log:<br>Based on the PSQI (Buysse et al. 1989), German adaption (Backhaus & Riemann 1996). Morning-/evening ratings on 7 consecutive days. | Sleep-EEG:<br>One-channel EEG device (Fp2-A1; electro-myogram; Som-nowatch, Ran-dersacker, GER). Sleep registration on a regular school day, following a day without exercise. | Questionnaire:<br>Athletes (mean weekly hours of vigorous exercise 12.69; SD=2.05) and non-Athletes (M=1.56; SD=1.02) | ------------- | t-test<br>ANOVA | **Positive association of subjective and objective sleep and being a male vigorous exerciser**<br>Compared with controls, male vigorous football players reported shorter SOL, *d**=0.61 [M], better sleep quality, *d**=3.59 [L], fewer WASO, *d**=1.54 [L], but shorter TST, *d**=1.36 [L] on week-nights. However, considering also weekend-nights, no sign. group differences were found for TST, as they had less weeknight to weekend night variation. Objective SE% was also higher for football players, *d**=2.59 [L], and SOL shorter, *d**=1.67 [L], although sleep-EEG registration was performed following a day without exercise. |
| *Delisle TT et al 2008* [90] | N=822 (m 366; f 456)<br>17.0 y (±0.81)<br>Epidemiological study: Data were collected from a large, diverse suburban high school (11th, 12th grade) in northeast Florida. Study analyzed baseline data collected from 2 prevention intervention trials. | Questionnaire:<br>1 item measuring the average quantity of sleeping hours (1=9 or more hours, 2=8hours, 3=7hours, 4=6 hours, 5=5 hours, or less). | ------------- | Questionnaire:<br>Adaption of the LTEQ to assess MPA and VPA within one week (Godin & Shepard 1985). Participants were then grouped into low, medium, and high MPA or VPA. | ------------- | ANOVA | **Positive Association of reported sleep h and VPA.**<br>MANOVA and pair wise analysis showed that a high level of VPA was significantly associated with longer sleep times (F=4.83, p=.01, *d**=-0.21 [S]). No differences were found for MPA and hours of sleep. |
| *Gerber M et al 2010* [91] | N=862 (m 223; f 639)<br>24.7 y (±5.91)<br>Students from the University of Basel (sport science, psychology, psychiatry, medicine) and the northwestern University of | Questionnaire:<br>*ISI* (Bastien et al. 2001)<br>*FEPS II* (Hoffmann et al. 1996);<br>*PSQI* (Buysee et al. 1989).: German adaption | ------------- | Questionnaire:<br>*OMQ* (Mäder et al. 2006); *Lack of PA*; 1 item of the *Swiss HEPA Survey* (Martin et al. 1999): Are you engaged in | ------------- | ANOVA<br>MANOVA | **Positive association of reported sleep and fitness, but not with exercise.**<br>*Wknd-nights:* Perceived lack of ex. (Wilk`s $\lambda$ =0.98, p<0.001) and perceived fitness (Wilk`s $\lambda$=0.97, P<0.001) showed sign. group differences. Ex. did not produce sign. results. *Wk-nights:* If fitness was used as predictor variable, both multivariate (Wilk`s $\lambda$=0.98, P<0.01) and univariate main effects occurred. Moderate and high fitness levels |

## Table 4.3 continued

| | | Measurements | | | | | |
|---|---|---|---|---|---|---|---|
| Author (year) | Sample Description | Assessing Sleep | | Assessing PA | | | |
| | $N_{anazlyzed}$ / Age / Population | Self-report | objective | Self-report | objective | Statistics | Results and discussion |
| | Applied Sciences (psychology, tourism, pedagogy, gymnastics) in the German-speaking northwestern part of Switzerland | (Backhaus & Riemann 1996) Destinction between wk / wknd nights | | enough PA to maintain good health?; *Fitness* Plante et al. 2000): 1 item ranging from 1-10 | | | were connected with reduced SOL. Sleep quality and perceived recovery in the morning improved with increasing fitness. Ex. and lack of ex. were not associated with sleep pattern.<br>Insomnia and fitness level: *d**=-0.34 [S]<br>Sleep quality and fitness level: *d**=0.32 [S]<br>Sleep restoration and lack of PA: *d**=0.24 [S]<br>Insomnia and lack of PA: *d**=0.19 [-] |
| *Gerber M et al 2014* [92] | N=42 (m 20; f 22)<br>21.2 y (±2.20)<br>Undergraduate students from the University of Basel, Switzerland who were recruited via word-of-mouth recommendation. | Questionnaire:<br>*ISI* (Bastien et al. 2001) | Sleep-EEG:<br>One-channel EEG device (Fp2-A1; electro-myogram; Som-nowatch, Ran-dersacker, GER). Sleep registration during a week night following | ------------- | Actigraph<br>A hip worn actigraph on 7 consecutive days (GTIM, Actigraph, Shalimar, FL, USA) | | **Positive association of being above VPA guidelines, fewer sleep complaints and objective sleep pattern.**<br>Adolescents above recommended ACSM vigorous PA guidelines reported less insomnia symptoms, *d**=1.00 [L] |
| *Holmberg LI et al 2008* [37] | N=1325 (m 775; f 550)<br>17.3 y (16-18 yrs.)<br>High-school students from a medium-sized town in mid-Sweden, 200km west of Stockholm. This age group represents a sub-sample in the study. There was also a group aged 13-15 yrs. | Questionnaire<br>2 questions:<br>did you have sleeping problems during the last week?<br>Did you feel tired during the last week? | ------------- | Questionnaire<br>Physical training at least once a week? | ------------- | LogR<br>OR | **Positive association of reported physical training and sleep.**<br>4 groups: boys good sleepers, boys bad sleepers, girls good sleepers, girls bad sleepers.<br>Lack of physical training was associated with poor sleep among girls, $log_e(2.594)=0.35$; 95% CI = 0.29-0.55, and among boys $log_e(2.774)=0.67$; 95% CI = 0.39-0.93<br>Girls: *d**=0.19 [-]<br>Boys: *d**=0.33 [S] |
| *Kalak N et al 2012* [18] | N=51 (m 24; f 27)<br>18.3 y (±0.89)<br>Students from a high-school, located in the canton of Basel-Landschaft, a district of the German-speaking north-western part of Switzerland. No intake of psychoactive or sleep-altering substances for 2 weeks. Students were randomly selected to either RG (running group) or control (CG). | Sleep log<br>21 consecutive days, covering weekdays and weekend days during school term (mid August until end September, high light exposure from early morning). Filled out in the morning and evening (see Brand et al., 2009).<br>Insomnia severity index (ISI, Bastien et al., 2001) | Sleep-EEG<br>Recordings were performed at home via a three-channel EEG device (Fp2-A1, C3-A2, C4-A1; SOMNOwatch™) before/after study. | Questionnaire<br>Mean weekly vigorous exercise was assessed with one question, asking for exercise hours per day and exercise days per week (hrs/week). | Supervision<br>Students of RG went running for 3 weeks on 5 consecutive school days before school started (7AM) for 30-37 min cross country in a group. CG hat 3x5 resting activities at the track field in a group. | ANOVAS repeated measures | **Positive association of moderate daily morning running with objective and subjective sleep**<br>An intervention involving running for 30 minutes in the morning daily during weekdays for 3 consecutive weeks significantly improved subjective sleep quality, $F(5,245)=5.98$, $p<.01$, $\eta^2=.11$, *d**=0.69 [M], decreased insomnia symptoms, $F(1,49)=26.57$, $p<.001$, $\eta^2=.11$, *d**=1.45 [L], and improved objective sleep pattern (SOL decreased, $F(1,49)=6.12$, $p<.01$, $\eta^2=.12$, *d**=0.69 [M], deep sleep increased, $F(1,49)=6.17$, $p<.01$, $\eta^2=.11$, *d**=1.70 [M], increased REM latency, $F(1,49)=4.05$, $p<.05$, $\eta^2=.09$, *d**=0.56 [M]). |
| *Lang C et al 2013* [48] | N=56 (m 28; f 28)<br>18.0 y (±1.36)<br>Students from two vocational schools in the German speaking central part of Switzerland | Questionnaire<br>Pittsburg Sleep Quality index (PSQI, Buysse et al., 1989); Insomnia severity index (ISI, Bastien et al., 2001). | Sleep-EEG<br>Sleep was recorded on one night via a one channel EEG-device (SOMNO-watch™) | Questionnaire<br>Two questions of the IPAQ (Craig et al., 2003) asking about how many days they engaged in vigorous PA during the last week, and average duration (per day). The same was done for moderate PA. | Accelerometer<br>A digital accelerometer (Somnowatch®) was attached at the participants' non-dominant wrist for three consecutive days and nights. moderate and vigorous PA from 10 min on were analyzed. | ANOVAs<br>MRA | **Positive association of increased PA and better subjective and objective sleep.**<br>Adolescents with high PA levels had longer TST, fewer wakening at night (subj. WASO and subj. PA: $R^2$= .204 / obj. PA: $R^2$= .151), fewer symptoms of insomnia (ISI and subj. PA: $R^2$=153 / obj. PA: $R^2$= .186), and higher sleep quality (obj. sleep efficiency and subj. PA: $R^2$=.321 / obj. PA: $R^2$= .306). However, gender influenced this pattern of results in that significant findings were only found between high self-reported PA levels and shorter perceived SOL, $F(1,36)=4.97$, $p<.05$, $\eta^2=.09$, *d**=0.76 [M], and less REM latency, $F(1,49)=8.19$, $p<.01$, $\eta^2=.19$, *d**=0.97 [L]. Though self-reported PA levels were a better predictor of good sleep than objectively assessed PA levels, gender was associated with sleep complaints; females reported more sleep complaints. Females were also less active than males. |
| *Lund HG et al 2010* [9] | N=1125 (m 420; f 705)<br>20.0 y (±1.3)<br>Students from a large private university located in the urban Midwestern US. Online survey (e-mail sent to all full-time undergrad students (n=5401). Female responder bias: although m/f were enrolled in equal proportions. | Questionnaire:<br>ESS (Johns, 1992), MES (Horne & Ostberg 1976), PSQI (Buysse et al. 1989). Scores were split: optimal (≤5), borderline (6-7), poor (≥8) sleep. | ------------- | Questionnaire:<br>Exercise frequency (h/wk) | ------------- | T-tests<br>MANOVA<br>MRA | **No association of reported exercise frequency (per wk) and sleep.**<br>Exercise frequency/wk was not a significant predictor of the PSQI score (t-.906, p>0.05). |
| *Ortega FB et al 2010* [59] | N= 416 (m 230; f 186)<br>15.4 y (±1.4)<br>Data were gathered as a part of the AVENA study (Gonzalez-Gross et al. 2003). Participants were adolescents from 5 Spanish cities (Granada, Murcia, Madrid, Zaragoza and Santander). | Questionnaire:<br>Weekdays:<br>1) When do you usually go to bed?<br>2) When do you usually get up in the morning?<br>3) Do you feel tired from your sleep when you wake up on? | ------------- | Questionnaire:<br>Do you undertake any physical sporting activity after school? Answer was classified as either no LT-PA or one or more LT-PA. | ------------- | LRA | **Negative association of reported short sleep duration and morning tiredness with participation in LT-PA.**<br>Male adolescents sleeping less than 8h are less likely to participate in LT-PA (OR 0.64, 95% CI 0.45-0.93, *d**=0.35 [S]). Girls: *d**=0.56 [M]. Morning tiredness substantially reduced the likelihood of participating in any LT-PA in both male and female adolescents (OR 0.49, 95% CI 0.34-0.69, *d**=0.27 [S]). |
| *Ortega FB et al 2011* [85] | N=678 (m/f ?)<br>15-16 y<br>Subsample of a total of 1172 Estonian and 1069 Swedish children (9-10) and adolescents (15-16). For this review, only the sample of adolescents was included. | Questionnaire:<br>Two items: 1) What time do you usually get up on a school day, 2) What time do you usually go to bet on a school day. Calculated was | ------------- | ------------- | Actigraph<br>4 consecutive d (>1 wknd day) worn on the hip (MTI model WAM 7164, Shalimar, Florida): MVPA and sedentary, | ρ (rho)<br>ANOVA<br>ANCOVA | **No association of objective physical activity and reported sleep duration**<br>Participants sleeping longer than 10h spent less time in sedentary activities and more time in MVPA (MPA, VPA) than those sleeping 10h or less (all p<0.001), but these associations were fully explained by age or sexual maturation. |

**Table 4.3 continued**

| Author (year) | Sample Description | Measurements: Assessing Sleep | | Measurements: Assessing PA | | Statistics | Results and discussion |
|---|---|---|---|---|---|---|---|
| | $N_{anazlyzed}$ / Age / Population | Self-report | objective | Self-report | objective | | |
| | | the sleep duration. Daylight length was used as one of the confounders in the analyses. | | | (min/d). Sedentary time <100counts/min. Cut offs for mod. and vig. PA (Trost et al. 2002). | | |
| *Ronspies S et al 2011* [86] | N=227 (m 108; f 119)<br>7th-8th grade<br>60% Caucasian and 40% Hispanic middle school students from 3 US Midwest school districts. For review, only results from 8th grade (≈ 14 yrs.) are reported. | <u>Questionnaire:</u><br>Sleep duration was reported in hours via the School Sleep Habits Survey. | ------------- | ------------- | <u>Pedometer</u><br>Walk4Life Pro pedometer, worn on 4 consecutive school days, recording both step count and activity time. | r | **Positive association of objective activity time and step count with reported hours of sleep duration.**<br>Pearson correlation coefficients indicated significant relationships for 8th grade girls among sleep duration (h) and step count (r=.65; p<.05, *d**=1.71 [L]) as well as activity time (r=.65; p<.05, *d**=1.71 [L]). For boys, the relationships between sleep and step count (r=.53; p<.05, *d**=1.25 [L]) as well as activity time (r=.58; p<.05, *d**=1.24 [L]) were slightly lower. Relationships were slightly stronger in Caucasian students. |
| *Tynjälä J et al 1993* [60] | N≈8000<br>15.5 y<br>This study was part of the international HBSC study (Austria, Belgium, Finland, Hungary, Israel, Norway, Scotland, Sweden, Switzer-land, Wales) 1985-1986. | <u>Questionnaire:</u><br>Sleeping habits of school nights: bed time and morning waking, inability to fall asleep, morning tiredness | ------------- | <u>Questionnaire:</u><br>Frequency of exercise during 1 week. | ------------- | PPMCC | **No association of reported exercise and sleep.**<br>No association of reported exercise frequency and bed time (all r< ± .10 except for Hungary r= .14). |
| *Tynjälä J et al 1999* [33] | N=1194 (m 576; f 618)<br>15.9 y<br>Finish adolescents which are part of the HBSC-Study (11-, 13- and 15 year-old, only 15 year olds filled out questions related to subjective sleep quality. | <u>Questionnaire:</u><br>1) How well do you usually sleep?<br>2) How often do you have difficulties in falling asleep?<br>3) How often do you wake up during the night? | ------------- | <u>Questionnaire:</u><br>LT-PA:<br>Frequency and duration of PA per week; activity in sport club | --------------- | SEM | **Positive association of reported sleep and LT-PA among girls, but not for boys.**<br>LT-PA predicts perceived sleep quality among girls ($R^2$=0.08), but not for boys. However, LT-PA proved to be the least important factor in associations with subjective sleep quality, compared to home atmosphere, self-perception and health habits. |
| *Wydahl A 1991* [88] | N=14 (m 0; f 14)<br>16-18 y<br>High-school girls from Alta, Norway (arctic circle). 6 athletes (members of local European-handball team), 8 non-athletes. Study: from September to December 1989. | <u>Log:</u><br>Filled out once a week (morning): A sleep score ranging from 1-11 was computed for each girl each week (Visser et al. 1979). High score = good sleep. | ------------- | <u>Activity-log</u><br>Daily: type, time, intensity for all PA. Participation in school activities was verified by P.E. teachers. Amount of activity (h) was calculated for each week. | ------------- | t-test<br>ANOVA | **Positive association of being an athlete and reported sleep remains stable from normal to darkness-period.**<br>Athletes had more activity (t=-7.80, p<.001), longer TST (t=-3.07, p<.01, *d**=-1.66 [L]), and higher mean sleep-scores than non-athletes (t=-6.01, p<.001, *d**=-3.25 [L]) at baseline and throughout fall (including normal to darkness-period). However, there was no time x group difference. |
| *Wydahl A 1991* [89] | N=435 (m 204; f 224)<br>16-18 y<br>Students of a Senior High School, city of Tromso, Norway (March/April). 74.9% of 621 responded to the questionnaire. | <u>Questionnaire:</u><br>Special sleep-score (items dealing with last night), general sleep-score (Visser et al., 1979 Norwegian translation from English translation of the Dutch version). | ------------- | <u>Questionnaire:</u><br>Physical fitness; hours of hiking/ skiing or walking last wknd. types of sport / PA >15 min, (frequency/ intensity of ex; inside/ outside) | ------------- | MRA | **Positive influence of reported PA on girl\`s, but not boy\`s general sleep. Positive influence of yesterdays PA on boy\`s, but not girl\`s last nights sleep.**<br>The better one evaluates one\`s physical fitness the better the average sleep quality (F=4.73; β=.17; p<.05). Separate analysis for sex reveal an influence only for girls (F=5.56; β=.29; p<.05). The second model included frequency and intensity of yesterdays exercise on last nights sleep. Significant findings were only found for boys (F=11.06; β=.54; p<.001). Exercise intensity was more predictive than frequency. |
| *Youngstedt SD et al 2003* [58] | N=43 (m 12;f 31)<br>22.9 y (±2.8)<br>Students enrolled in a Sleep Research class at the University of Rochester (study 1). | <u>Sleep-Log</u><br>21-105 days (M 102 days): SOL, TST, WASO, SE Data analysis with mean values | ------------- | <u>Activity-Log</u><br>Including a question about total daily exercise duration (min7day). Data analysis with mean values | ------------ | ρ (rho)<br>t-tests | **No association of reported daily exercise and sleep.**<br>None of the within-subjects correlation of subjective mean ex. duration and mean sleep were sign. (p<.04). T-tests among the most active and least active days revealed two pos. effects for WASO, t(1,30)=2.85, p<.01, *d**=1.02 [L], and SE, t(1,30), p<.05, *d**=0.80 [L]. Post hoc analysis with a restricted sample (n=11) of higher daily ex. deviation did not show a significant correlation between ex. and sleep (p≥.06). |

*Notes.* ACSM: American college of sport medicine, d* = utilized effect size, ESS: Epworth sleepiness scale, f: females, ISI: insomnia severity index, m: males, OSA: commonly used sleep questionnaire in Japan, PSQI: Pittsburgh sleep quality index, SE: sleep efficiency, SOL: sleep onset latency, TST: total sleep time, WASO: waking after sleep onset; y: years.

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# CHAPTER 5

## Increased self–reported and objectively assessed physical activity predict sleep quality among adolescents.

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# INCREASED SELF-REPORTED AND OBJECTIVELY ASSESSED PHYSICAL ACTIVITY PREDICT SLEEP QUALITY AMONG ADOLESCENTS


## ABSTRACT

Both scientists and the general public assume that physical activity (PA) is an effective, non-pharmacological approach to improvement in sleep quality. However, objective and reliable data on this relationship are scarce, particularly for adolescents. Therefore, the aims of the present study were to test the relationship by assessing both physical activity and sleep subjectively and objectively. A total of 56 adolescent vocational school students (Mean age = 17.98, *SD* = 1.36; 28 males, 28 females) participated in the study. Sleep and physical activity were subjectively assessed via questionnaires. Accelerometers objectively assessed PA, while sleep-EEG devices objectively assessed sleep. The data supported our prediction that adolescents with high physical activity levels would have longer TST, fewer wakening at night (WASO), fewer symptoms of insomnia, and higher sleep quality. However, gender influenced this pattern of results in that significant findings were only found between high self-reported physical activity levels and shorter perceived sleep onset latency (SOL). Though self-reported physical activity levels were a better predictor of good sleep than objectively assessed physical activity levels, gender was associated with sleep complaints; females reported more sleep complaints. Results indicate that among a non-clinical sample of adolescents increased physical activity is favorably associated with restoring sleep. Therefore, physical activity seems beneficial not only for physical and mental health, but also for sleep restoration.


**Key words:** Actigraphy; adolescent; exercise; insomnia; sleep deprivation; sleep-EEG

## INTRODUCTION

Adolescence is defined as a vulnerable period characterized by several changes in physiological, psychiatric, socio-cultural and psychological factors that affect health and behavior, including sleep quality and quantity [1-4]. For vocational students, additional responsibilities arise in the transition to a vocational school and balancing academic and job requirements[5]. Neurobiological sleep-regulatory mechanisms also play a role; there are underlying changes in both circadian and homeostatic components of sleep which influence the sleep-wake cycle, as well as sleep timing, duration, and architecture [2, 6, 7]. The most striking change in sleep architecture is the decrease in slow wave sleep (SWS) [8-10].

Whereas poor sleep is associated with maladaptive functioning and a number of psychiatric and physical diseases [1], there is a dearth of knowledge on the sleep quality of adolescents attending vocational education and training. Pharmacological and psychotherapeutic treatments of insomnia have proved successful but entail negative side effects or require professional intervention [11, 12]. In contrast, physical activity (PA) is an alternative favored by many sleep experts [13-15]. There are two main hypotheses about the mechanism through which physical activity positively influences sleep. First, physical activity produces physiological changes favorable to sleep regulation. For example, Dworak et al. [17] were able to show that among young adolescents (12.6 years old) high-intensity exercise resulted in a significant rise in the proportion of SWS, less sleep in stage 2, greater sleep efficiency (SE %), and shorter sleep onset latency (SOL). Kalak et al. [18] assessed the sleep of 19 year olds via sleep-EEGs after three consecutive weeks of morning running, compared to a control condition. Objective sleep improved (SWS increased; SOL decreased) in the running group compared to the control group. The second hypothesis is that the sleep-promoting effects of physical activity are mediated via psychological functioning [19-21], by decreased symptoms of depression [22, 23], anxiety [24, 25], and stress [26, 27]. Thus, in previous studies of adolescents, we have found that self-reported exercise was positively related to adolescents' sleep and psychological functioning: Adolescent exercisers reported better sleep patterns, while males with low exercise levels were at increased risk for poor sleep and psychological functioning [12]. In a second study [23], objectively assessed but not self-reported sleep was significantly related to exercise level, higher positive coping and curiosity scores, and lower depressive symptom scores.

However, many adolescents reduce their physical activity levels during this period of life [28-30]. Vocational students in particular report lower levels of exercise than peers attending regular high schools [31, 32]. However, the relationship between physical activity and the functional importance of sleep among vocational students has received little attention thus far. This is surprising, given that 74% of all secondary school diplomas in Switzerland are granted to students with vocational education and training (VET) [33]. In Switzerland, VET serves as the primary gateway to numerous occupations. Most students start at the age of 16 or 17. Swiss VET combines apprenticeships in a company and vocational training in a school; students work three to four days a week in a company and attend a vocational school on one to two days a week. While apprentices receive a limited salary for their work in the company, they often have equal workloads in terms of working hours as well as responsibilities similar to adult employees. Overall, compared to academic high school students, vocational students face a dual burden of academic and work requirements: Depending on vocation, students have to manage this challenging condition for three to four years. With respect to the relationship between sleep and work, in one study the number of working hours was negatively correlated with hours of sleep, and decreased sleep quality was correlated with increased strain, depression and anxiety [34]. Additionally, employees who report poor sleep or symptoms of insomnia tend to consume more medical resources [35] and at work they exhibit lower self-esteem [36], lower work efficiency and higher absenteeism rates [37, 38]. Collectively, these findings suggest that adolescents attending vocational schools are at greater risk for developing sleep disturbances or sleep-related psychological dysfunction.

Despite the evidence from two studies [17, 18] that physical activity has beneficial effects on sleep, findings from cross-sectional studies among adolescents remain inconclusive [15, 21, 39-42]. Whereas epidemiological data from self-reports have consistently revealed a positive relationship between physical activity and sleep [43-45], findings are difficult to interpret and compare given the vast array of different measurement methods in this field of research. To the best of our knowledge, no previous study has assessed physical activity and sleep via both subjective and objective methods in the adolescent population. Therefore, the present study aims to establish findings for the adolescent population, and overcome methodological limitations, by assessing physical activity and sleep both subjectively and objectively.

Five hypotheses were tested (see Figure 4.1). (1) Physical activity levels as assessed subjectively by questionnaire and objectively by accelerometer will correlate positively [46, 47]. (2) Sleep quality as assessed by questionnaires and by sleep-EEG device will positively intercorrelate [48]. Subjective sleep quality will be positively associated with both (3a) subjective level [12, 23], and (3b) objective physical activity level [49]. We further expected that more favorable objectively assessed sleep will be related to higher (4a) subjective, and (4b) objective physical activity levels [50, 51]. (5) Following cognitive models of insomnia [52], our final hypothesis was that subjective physical activity levels would better predict sleep quality than objective physical activity levels.

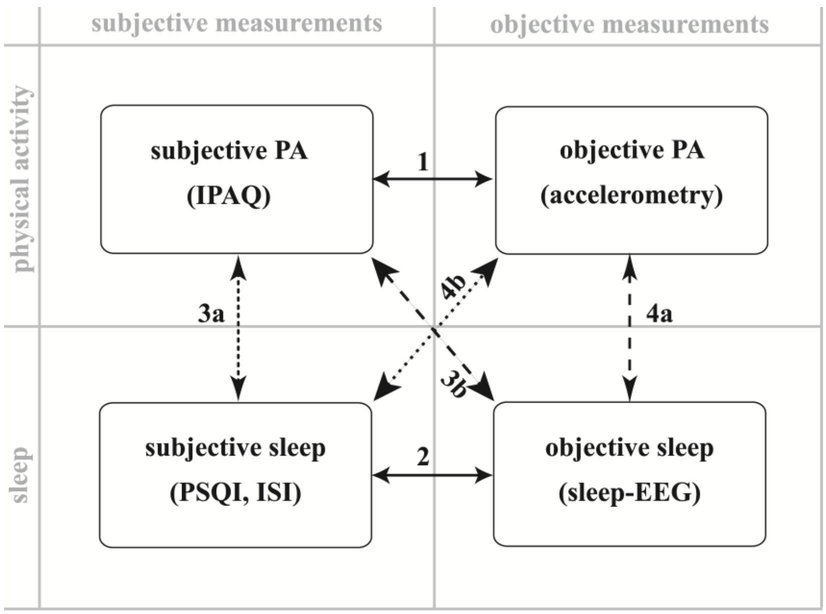


**Figure 5.1. Visual representation of hypotheses (excluding hypothesis 5)**
IPAQ=International Physical Activity Questionnaire [56], PSQI=Pittsburgh Sleep Quality Index [57], ISI=International Severity Index [55].

## MATERIALS AND METHOD

### Participants and procedure

A sample of 1581 young people (age: 16-25 yrs, mean=17.98, *SD* = 1.36, 43% females) attending two vocational schools in central and German speaking Switzerland completed a series of questionnaires related to PA, psychological functioning and sleep (see below for details). They were all participants in the EPHECT-study (www.ephect.unibas.ch), a research project focusing on the interplay between stress, coping, sleep and health among Swiss vocational students. Baseline data were collected in August 2010. All participants completed the questionnaires during class hours (range 20-40 minutes). Participants received detailed information about the purpose of the study and about the voluntary nature of their participation. They were assured confidentiality and provided informed written consent prior to completing the questionnaires. Parents' informed consent was required for those under 18 years old. The study was approved by the local ethical committee and was performed according to the ethical standards in the Declaration of Helsinki.

Next, from this larger sample 56 adolescents ($M_{age}$ = 17.98, SD = 1.36; 28 males, $M_{age}$ = 18.14, SD = 1.17; females, $M_{age}$ = 18.21, SD = 0.89) were selected for further objective physical activity and sleep assessments. The following inclusion criteria were applied: 1) Willing and able to participate in further assessments of physical activity and sleep, consisting of wearing an accelerometer for three consecutive days and nights, and sleeping for one night with a sleep-EEG. 2) Reporting low or high scores (based on median splits) on both a 30-item short version of the Adolescents Stress Questionnaire (ASQ) [53] (median = 69.0, possible range: 0-150) [54] and the 4-item version of the Insomnia Severity Index (ISI) [55] (median=8.0; possible range: 0-20). 28 participants were randomly selected from each group, stratified for gender (50% female). Objective measurements were carried out shortly after the adolescents had completed the survey questionnaires.

Three participants (two males, one female) were excluded from the analyses because accelerometer recordings were missing. There were 18 further exclusions (16 males, 2 females) due to missing EEG-recordings. Thus, complete subjective and objective data for physical activity and sleep were available from 37 participants (13 males, 24 females). Independent samples t-tests revealed no differences between participants with complete vs. incomplete data for sleep and physical activity parameters. Therefore, all analyses are based on the 37 participants with complete data.

### Measurements

*Assessment of subjective* PA

To assess self-reported PA, participants indicated how many days they had engaged in vigorous physical activity over the previous week. The response categories ranged from 0 to 7 days. In addition, participants were asked to indicate the average duration (per day) for the days they engaged in these activities. Physical activity frequency multiplied by duration yielded hours of weekly exercise and sport. Moderate physical activity was assessed in a similar way. Both items were taken from the International Physical Activity Questionnaire (IPAQ) [56]. Following the IPAQ (see www.ipaq.ki.se/scoring.pdf), guidelines for data processing and analysis physical activity time exceeding '3 hours' was set to '3 hours'. Therefore, 21 hours of moderate and vigorous physical activity per week was the maximum value. The guideline further suggests commuting total moderate and vigorous physical activity minutes per week into MET-minutes/week (metabolic equivalent of task). Moderate physical activity minutes were multiplied by 4.0 METs and vigorous physical activity minutes by 8.0 METs. Moderate to vigorous physical activity (MVPA) was then calculated by summing across moderate physical activity METs and vigorous physical activity METs. Ottevaere et al. [47] showed that the IPAQ predicts cardio-respiratory fitness among adolescents equally as well as actigraph accelerometers.

For ANOVAs, participants were split into two activity groups (high vs. low subjective physical activity level). Cut-off values were applied according to the CDC (Centers for Disease Control and Prevention) recommendations for PA, suggested in the IPAQ-manual. To meet recommendations, participants needed ≥ 5 days/week of moderate activity (for ≥ 30 minutes) or ≥ 3 days/week of vigorous activity (for ≥ 20 minutes) or ≥ 5 days/week of any combination achieving a total physical activity of at least 600 MET-minutes/week [57]. Participants in the subjective high physical activity level group (*N* = 23; 12 males, 11 females) reached minimum physical activity recommendations, whereas those in the subjective low physical activity level group (*N* = 14; 1 male, 13 females) were below the recommended level.

*Assessment of objective PA*

A digital accelerometer (Somnowatch®; Somnomedics, Randersacker, Germany) was worn on participants' non-dominant wrist for three consecutive days and nights. All participants were instructed in how to handle the accelerometer the day before the measurements. The tool registered every movement above 0.012 g in bi-axial direction. The data were recorded in 40-second intervals. The activity charts of every measurement day were visually analyzed. Two cut-off points were used to distinguish between moderate (500 counts) and vigorous physical activity intensity (1000 counts). Following the IPAQ procedure, every episode of moderate to vigorous with a duration of > 10 minutes was analyzed. For further analysis, moderate physical activity minutes were multiplied by 4.0 METs and vigorous physical activity minutes by 8.0 METs. Moderate to vigorous physical activity (MVPA) was calculated by summing up moderate physical activity METs and vigorous physical activity METs. For ANOVAs, participants were classified as either high (*N* = 15; 6 males; 9 females) or low (*N* = 22; 7 males, 15 females) objective physical activity levels. Cut-off values were applied according to the CDC recommendations for PA, similarly to subjective physical activity level groups.

*Assessment of subjective sleep*

Sleep quality was assessed with the Pittsburgh Sleep Quality Index (PSQI) [58; German adaptation 59]. Participants were asked to *think of two typical weekdays within the last two weeks and rate the following sleep items*. For evenings, participants answered questions on an 8-point Likert scale about *tiredness during the day* (8 = not at all tired), *concentration during the day* (8 = very good concentration), and *mood at bedtime* (8 = very good mood). For mornings, the questionnaire asked about *waking mood* (8 = very good mood), *sleep quality* (8 = very good sleep quality), and *feeling restored* (8 = completely restored), using the same scale. In addition, information about sleep onset latency (SOL) (in minutes), number of awakenings (WASO), and total sleep time (TST) (in hours and minutes) were reported. Evidence for the reliability and validity of the PSQI has been provided previously [12, 60, 61].

Additionally, participants completed four items of the Insomnia Severity Index (ISI) [55]. The items refer in part to the DSM-IV criteria for insomnia DSM-IV-TR criteria for insomnia [62], asking participants about *difficulty falling asleep*, *difficulties staying sleep*, and *early morning wakening*. A fourth item queried current sleep satisfaction. Answers were given on a 5-point rating scale ranging from 0-4 (*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).

*Assessment of objective sleep*

Sleep EEG assessments were based on three days and nights of accelerometry, using a portable EEG-recording device (Fp2-A1; electrooculogram; electromyogram; SOMNOwatch$^{TM}$, Randersacker, Germany). Previous experience with simple sleep-EEG devices has proved to provide satisfactory data [23, 60, 63]. The advantage of a portable sleep-EEG device is that participants can sleep at home in familiar surroundings. Sleep registration was performed following a regular day at school or at work. Students were requested to adhere to their normal evening routines. Trained study assistants applied sleep-EEG devices at students` homes shortly before bedtime. Sleep polygraphs were visually analyzed by two experienced raters according to the standard procedures [64]. Sleep parameters were analyzed according to the definitions in the standard program described by Lauer et al. [65]. The device provided assessment of total sleep time (TST), sleep period time (SPT), SOL, sleep efficiency (SE %), stages 1 to 4, light sleep (stages 1 and 2), slow wave sleep (SWS) (stages 3 and 4), REM- sleep, REM-sleep latency, and WASO.

*Socio-demographic background*

Information about socio-demographic background was requested in the first section of the questionnaire. In addition to age and gender, students estimated the financial situation of their family compared to their peers on a 5 point scale from 1 (*much worse)* to 5 *(much better*).

**Data analysis**

The association of physical activity and sleep with age and family financial situation was tested using bivariate Pearson's Product Moment correlations. Associations between objective and subjective physical activity and between objective and subjective sleep data were analyzed using Pearson`s correlations. Gender differences for physical activity and sleep were analyzed using t-tests. Test results with an alpha level of below .05 were reported as significant. Due to the small sample size, we also considered effect sizes to interpret data. Following Cohen [66], effect sizes of .20 > $d$ < .49 were considered small ([S] i.e., negligible practical importance), .50 > $d$ < .79 medium ([M] i.e., moderate practical importance), and $d \geq .80$ large ([L] i.e., crucial practical importance). The relationship between subjective physical activity and subjective and objective sleep parameters was explored using a series of one-way ANCOVAs with the factor group (high vs. low subjective physical activity levels), and with gender as covariate. Similarly, the relationship between objective physical activity and subjective and objective sleep parameters was explored using one-way ANCOVAs with the factor group (high vs. low objective activity levels), and with gender as covariate. Effect sizes for ANOVAs (partial eta-squared [$\eta^2$]) were regarded as small [S] if .01 > $\eta^2$ < .059, medium [M] if .06 > $\eta^2$ < .139, and large [L] if $\eta^2 \geq .14$ [67].

Additionally, subjective and objective physical activity (moderate and vigorous intensity) and gender were used as predictor variables in linear regression analyses (stepwise backward) to examine the association between physical activity and gender on subjective and objective sleep parameters. Inclusion criteria for the regression analyses were sleep variables with substantial effect sizes in the previous ANCOVAs. Due to the intercorrelation of the variables (subjective vs. objective and moderate vs. vigorous PA), separate regressions were calculated using different combinations of predictors. Durbin-Watson statistics were calculated to test for independence of residuals. Given the number of predictors and sample size in this study, Durbin and Watson suggest that if *ddU* < 1.06, predictors should be considered as intercorrelated, and if *ddL* > 1.45, predictors are not intercorrelated. On this basis, results of the Durbin-Watson coefficients were satisfactory (1.50 – 2.55). Effect sizes for multiple $R^2$ [$f^2$] were regarded as small [S] if .02 > $f^2$ < .24, medium [M] if .25 > $f^2$ < .39, and large [L] if $f^2 \geq .40$ [68]. All statistical analyses were performed using SPSS 20.0 (IBM Corporation, NY, USA).

## RESULTS

### Time spent in physical activity

The reported average time spent in physical activity was 21.58 minutes, *SD* = 25.58, for moderate physical activity (males: *M* = 24.58, *SD* = 28.47; females: M = 18.35, SD = 22.15) and 31.96 minutes, SD = 31.69, for vigorous physical activity (males: *M* = 41.35, *SD* = 34.46; females: *M* = 21.88, *SD* = 25.32). In contrast, objective measurements revealed 9.87 minutes, *SD* = 9.44 of moderate physical activity (males: *M* = 11.67, *SD* = 8.97; females: *M* = 8.08, *SD* = 9.92) and 4.59 minutes, *SD* = 7.79, of vigorous physical activity (males: *M* = 6.67, *SD* = 8.67; females: *M* = 2.43, *SD* = 3.98). Interestingly, 6.98 minutes (*SD* = 11.74) or 71% of the moderate physical activity and 4.06 minutes (*SD* = 7.79) or 88% of the vigorous physical activity occurred during school PE lessons.

The results show that 66% of the sample estimated their physical activity level as high, whereas objective physical activity measurements reveal that 53% did not meet the health recommendations for physical activity [57].

### Association between socio-demographic background, financial situation, physical activity and sleep

Age and family financial background were uncorrelated with subjective or objective PA, sleep EEG-recordings, subjective sleep parameters or insomnia symptoms (all $r < .22$; all $p > .05$).

### Association between gender, financial situation, physical activity and sleep

Compared to males, females reported lower levels of MVPA MET/week, $t(36) = -2.54$, $p < .05$, $d = 0.85$ [L], and had lower objective MVPA MET/week $t(36) = -2.41$, $p < .05.$, $d = 0.80$ [L]. Females also scored higher on the insomnia severity index, $t(36) = 3.05$, $p < .01$, $d = 1.02$ [L], while sleep-EEG recordings revealed a higher SE (%) among female students, $t(36) = 2.54$, $p < .05$, $d = 0.85$ [L], and longer TST, $t(36) = 2.54$, $p < .05$, $d = 0.85$, but fewer stage shifts, $t(36) = -3.05$, $p < .01$, $d = -1.02$ [L], and more wakening at night, $t(36) = -2.08$, $p < .07$, $d = 0.69$ [M]. The PSQI revealed no gender differences with regard to subjective sleep quality or daytime functioning. In addition, no gender differences were found for age or financial situation.

In summary, females are less involved in MVPA and report more insomnia symptoms than males, although sleep-EEG data do not fully confirm this pattern.

### Correlations between subjective and objective PA

Table 5.1 provides the correlations between self-reported and objective PA. High correlations were observed between subjective and objective vigorous physical activity ($r$ = .53, $p$ < .01) and moderate correlations between subjective and objective MVPA ($r$ = .40, $p$ < .01). Moderate objective physical activity was not correlated with any of the other activity variables. In summary, the results show a relatively high correspondence between the IPAQ and the accelerometer for vigorous PA, but not for moderate PA.

**Table 5.1**
Correlations between self-reported and objectively assessed physical activity levels ($N$ = 37)

| | Objective Physical Activity | | |
|---|---|---|---|
| | Moderate PA (MET/week) | Vigorous PA (MET/week) | MVPA (MET/week) |
| Self-reported Physical Activity | | | |
| Moderate PA (MET/week) | .07 | .27+ | .23+ |
| Vigorous PA (MET/week) | .10 | .53** | .44** |
| MVPA (MET/week) | .09 | .49** | .40** |

Correlations: Pearson`s $r$, two-tailed. + $p$<0.1; *$p$<0.05; **$p$<0.01; ***$p$=0.001.

### Correlations between subjective and objective sleep

Table 5.2 gives the correlations between all subjective and objective sleep parameters. The general pattern of results was such that subjective sleep continuity and quality showed no to weak correlations with objective measurements of sleep continuity and sleep fragmentation. Moderate correlations were found among the following sleep parameters.

Longer objective TST was correlated with lower scores for feeling restored, $r$ = -.36, $p$ < .05. Longer objective SOL was correlated with lower perceived sleep quality, $r$ = -.45, $p$ < .01, and more tiredness during day, $r$ = -.43, $p$ < .05. Higher objective SE (%) was correlated with higher scores for insomnia, $r$ = .36, $p$ = <.05, and feeling restored, $r$ = -.33, $p$ < .05. More objective stage shifts were correlated with higher perceived sleep quality, $r$ = .32, $p$ < .05. Longer objective WASO (min) were correlated with lower scores for insomnia, $r$ = -.34, $p$ < .05, shorter subjective SOL, $r$ = .43, $p$ < .05, and subjective TST, $r$ = -.36, $p$ < .05. Less stage 2 sleep (%) was correlated with shorter subjective TST, $r$ = .34, $p$ < .05. More objective stage 3 sleep (%) was correlated with longer subjective TST, $r$ = -.33, $p$ < .05, and objective stage 4 sleep (min) was correlated with higher scores for insomnia, $r$ = .43, $p$ < .01. Less light sleep (stages 1 + 2) (min) was correlated with longer subjective TST, $r$ = .36, $p$ < .05, and more SWS (stages 3 + 4) (%) was correlated with shorter subjective TST, $r$ = -.32, $p$ < .05. Additionally, the sum scores of the ISI and the PSQI were correlated, $r$ = -.41, $p$ < .01.

**Table 5.2.**
Correlations between self-reported and objectively assessed sleep variables, and daily performance ($N$ = 37)

| | "Within the last two weeks, please think of two typical weekdays and rate the following sleep items" | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ISI | PSQI | | | | | | | | |
| Sleep EEG recordings | Total score | SOL (min) | WASO | TST (h) | Sleep quality | Feeling restored | Mood morning | Mood evening | Tiredness dd | Concen-tration dd |
| SPT (min) | 0.09 | -0.05 | 0.06 | 0.22 | -0.01 | -0.28+ | -0.02 | -0.05 | -0.09 | -0.02 |
| TST (min) | 0.21 | 0.01 | 0.12 | 0.26 | -0.06 | -0.36* | -0.09 | -0.12 | -0.08 | -0.06 |
| SOL (min) | 0.8 | -0.15 | -0.14 | -0.02 | -0.45** | -0.05 | -0.22 | -0.08 | -0.43* | -0.21 |
| Sleep efficiency (%) | 0.36* | 0.05 | 0.26 | 0.24 | -0.19 | -0.33* | -0.12 | -0.22 | 0.01 | -0.09 |
| Stage shifts (index) | -0.24 | -0.10 | 0.00 | -0.25 | 0.32* | 0.06 | 0.18 | -0.08 | 0.02 | -0.08 |
| Awakenings after SOL (min) | -0.34* | 0.43* | -0.18 | -0.36* | 0.09 | -0.02 | 0.06 | 0.01 | -0.10 | -0.24 |
| REM sleep latency (min) | 0.09 | 0.28+ | -0.15 | -0.14 | 0.11 | 0.11 | -0.10 | -0.15 | 0.18 | 0.15 |
| Stage 1 (min) | -0.13 | -0.17 | 0.01 | -0.18 | 0.15 | 0.15 | 0.12 | 0.04 | 0.10 | -0.08 |
| Stage 1 (% of TST) | -0.21 | -0.16 | -0.03 | -0.25 | 0.21 | 0.28+ | 0.14 | 0.09 | 0.14 | -0.03 |
| Stage 2 (min) | 0.24 | 0.06 | 0.06 | 0.34* | -0.03 | -0.32+ | -0.18 | -0.06 | -0.10 | -0.03 |
| Stage 2 (% of TST) | 0.17 | 0.08 | -0.03 | 0.34* | 0.02 | -0.17 | -0.17 | 0.01 | -0.07 | 0.00 |
| Stage 3 (min) | -0.14 | 0.13 | 0.06 | -0.26 | 0.23 | -0.08 | 0.09 | -0.13 | 0.04 | -0.03 |
| Stage 3 (% of TST) | -0.15 | 0.16 | 0.05 | -0.33* | 0.21 | 0.02 | 0.09 | -0.10 | 0.04 | -0.03 |
| Stage 4 (min) | 0.43** | -0.17 | -0.04 | -0.08 | -0.05 | -0.08 | 0.02 | -0.11 | -0.02 | -0.08 |
| Stage 4 (% of TST) | -0.03 | -0.16 | -0.08 | -0.18 | -0.04 | 0.06 | 0.05 | -0.08 | 0.03 | -0.05 |
| Light Sleep (stages 1+2) (min) | 0.24 | 0.04 | 0.06 | 0.36* | -0.03 | -0.31+ | -0.19 | -0.06 | -0.07 | -0.05 |
| Light sleep (% of TST) | 0.13 | 0.05 | -0.03 | 0.30+ | 0.06 | -0.12 | -0.14 | 0.02 | -0.04 | -0.01 |
| Slow wave sleep (stages 3+4) | 0.01 | 0.17 | -0.04 | -0.30+ | 0.06 | -0.13 | 0.02 | -0.19 | -0.03 | -0.10 |
| Slow wave sleep (% of TST) | -0.10 | -0.07 | -0.05 | -0.32* | 0.07 | 0.06 | 0.09 | -0.12 | 0.04 | -0.06 |
| REM sleep (min) | 0.04 | 0.04 | 0.19 | 0.11 | -0.20 | -0.06 | 0.05 | 0.10 | -0.03 | 0.09 |
| REM sleep (% of TST) | -0.10 | 0.02 | 0.16 | -0.04 | -0.24 | 0.14 | 0.13 | 0.17 | 0.10 | 0.12 |

Correlations: Pearson`s r, two-tailed; SPT=sleep period time; TST=total sleep time; SOL=sleep onset latency; REM=rapid eye movement; WASO=waking after sleep onset; dd=during day; Correlations: Pearson`s r, two-tailed. + $p$<0.1; *$p$<0.05; **$p$<0.01; ***$p$=0.001. Note that higher ratings for the variables sleep quality, feeling restored, mood morning and mood evening, reflect higher sleep quality. Higher ratings for the variables difficulty falling asleep, difficulty staying asleep

**Sleep patterns in adolescents with high and low subjective and objective physical activity levels**

Table 3 provides an overview of the descriptive and inferential statistics for subjectively and objectively assessed sleep parameters as a function of PA-group (high vs. low subjective and objective PA). After controlling for gender, adolescents who reported high physical activity levels had shorter sleep onset latencies, $F(1,36) = 4.97$, $p < .05$, $\eta = .09$ [M], and longer REM latencies, $F(1,36) = 8.19$, $p < .01$, $\eta = .19$ [L]. Higher objectively assessed physical activity was associated with higher REM latencies, $F(1,36) = 3.60$, $p < .07$, $\eta = .10$ [M]. However, the gap between subjective and objective physical activity level groups is not of clinical relevance, as both are within the normal range for healthy sleepers (90 min ± 30 min). REM latency shorter than 20 minutes (sleep onset REM) is of concern, which is often associated with narcolepsy or depression, but did not occur within this sample.

Although there were few moderate to large effect sizes, there appears to be a trend across the data that supports a relationship between physical activity and sleep.

**Predicting self-reported and objective sleep with physical activity and gender**

To further examine whether sleep is associated with physical activity and gender, a series of multiple regressions was calculated (Table 5.4). Results from the multiple regression analyses showed a trend toward self-reported WASO being predicted by lower levels of vigorous PA, $\beta = .25$, $p = .057$, but after controlling for gender this association weakened considerably. In contrast, two other trends appeared; self-reported SOL, $\beta = -.26$, $p = .064$ and objective SOL, $\beta = -.30$, $p = .077$ were positively predicted by higher levels of vigorous PA, independent of gender.

In summary, vigorous physical activity level seemed to be a better predictor of good sleep than moderate PA, and self-reported physical activity level seemed to be a better predictor than objective PA. However, self-reported physical activity level was a better predictor for self-reported sleep, while objective physical activity level had a stronger influence on objective sleep. Males reported fewer sleep complaints than females.

**Table 5.3**

Differences in self-reported/objectively assessed sleep patterns between adolescents with self-reported PA above (high PA level) / below recommendations (low PA level) ($N$ = 37)

| | Self-reported PA groups | | Statistical analyses | | | | Objective PA groups | | Statistical analyses | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High PA level | Low PA level | Group | | Covariate Gender | | High PA level | Low PA level | Group | | Covariate Gender | |
| | [a]M (SD) | [a]M (SD) | $F$ | $\eta^2$ | $F$ | $\eta^2$ | [a]M (SD) | [a]M (SD) | $F$ | $\eta^2$ | F | $\eta^2$ |
| **Self-reported sleep** | | | | | | | | | | | | |
| TST (min) | 444.29 (10.26) | 429.94 (14.74) | 0.59 | .01 | 3.29* | .06 | 449.77 (12.05) | 430.84 (10.94) | 1.32 | .03 | 3.46$^{+}$ | .07 |
| SOL (min) | 15.19 (2.43) | 25.07 (3.50) | 4.97* | .09 | 1.47 | .03 | 17.30 (3.01) | 19.58 (2.73) | 0.31 | .00 | 0.17 | .00 |
| WASO (number) | 0.68 (0.18) | 0.45 (0.26) | 0.48 | .01 | 8.98** | .15 | 0.51 (0.22) | 0.68 (0.20) | 0.33 | .00 | 7.74** | .13 |
| [b]Feeling restored | 4.63 (0.32) | 4.72 (0.46) | 0.02 | .00 | 3.00$^{+}$ | .06 | 4.82 (0.38) | 4.53 (0.34) | 0.31 | .01 | 2.82$^{+}$ | .05 |
| [b]Waking mood | 4.75 (0.36) | 3.76 (0.51) | 2.34 | .05 | 0.17 | .00 | 4.31 (0.43) | 4.50 (0.39) | 0.10 | .00 | 0.09 | .00 |
| [b]Mood evening | 5.93 (0.27) | 5.65 (0.39) | 0.33 | .01 | 0.45 | .01 | 5.91 (0.32) | 5.76 (0.29) | 0.12 | .00 | 0.81 | .02 |
| [b]Daytime tiredness | 5.58 (0.35) | 5.01 (0.50) | 0.60 | .01 | 0.07 | .00 | 5.55 (0.41) | 5.13 (0.37) | 0.56 | .01 | 0.01 | .00 |
| [b]Daytime concentration | 5.71 (0.25) | 5.57 (0.36) | 0.10 | .00 | 0.00 | .00 | 5.87 (0.30) | 5.48 (0.27) | 0.34 | .02 | 0.00 | .00 |
| [b]Sleep quality | 5.38 (0.30) | 5.11 (0.44) | 0.24 | .01 | 2.07 | .04 | 5.28 (0.36) | 5.29 (0.33) | 0.00 | .00 | 3.10$^{+}$ | .06 |
| [c]Insomnia (ISI total Score) | 2.18 (0.14) | 2.45 (0.20) | 1.15 | .02 | 6.01* | .10 | 2.28 (0.18) | 2.30 (0.16) | 0.00 | .00 | 9.48** | .16 |
| **Objective sleep** | | | | | | | | | | | | |
| TST (min) | 395.53 (11.35) | 398.79 (14.96) | 0.02 | .00 | 4.61* | .12 | 400.68 (13.40) | 393.71 (11.06) | 0.16 | .01 | 6.31* | .16 |
| SOL (min) | 9.28 (2.00) | 10.71 (2.58) | 0.18 | .01 | 0.25 | .01 | 9.02 (2.31) | 10.37 (1.91) | 0.20 | .01 | 0.55 | .02 |
| Sleep efficiency (%) | 92.77 (1.31) | 91.56 (1.72) | 0.28 | .01 | 12.44*** | .27 | 93.62 (1.53) | 91.41 (1.26) | 1.24 | .04 | 14.64*** | .30 |
| Stage shifts (index) | 101.12 (6.21) | 107.80 (8.19) | 0.38 | .01 | 8.73** | .20 | 108.54 (7.30) | 100.31 (6.03) | 0.75 | .02 | 8.62** | .20 |
| WASO (min) | 24.06 (5.72) | 30.78 (7.54) | 0.46 | .01 | 7.41** | .18 | 22.26 (6.74) | 29.57 (5.56) | 0.70 | .02 | 7.75** | .19 |
| REM latency (min) | 80.84 (6.67) | 114.10 (8.79) | 8.19** | .19 | 3.26$^{+}$ | .09 | 105.67 (8.36) | 85.08 (6.90) | 3.60$^{+}$ | .10 | 0.13 | .00 |
| Stage 1 (%) | 2.75 (0.32) | 2.90 (0.42) | 0.07 | .00 | 5.23* | .13 | 2.68 (0.38) | 2.90 (0.31) | 0.19 | .01 | 6.09* | .15 |
| Stage 2 (% ) | 46.72 (1.90) | 44.55 (2.51) | 0.43 | .01 | 4.40$^{+}$ | .11 | 45.87 (2.26) | 45.92 (1.87) | 0.00 | .00 | 4.00$^{+}$ | .11 |
| Stage 3 (%) | 7.45 (0.80) | 9.03 (1.06) | 1.27 | .04 | 3.18$^{+}$ | .09 | 8.50 (0.96) | 7.74 (0.80) | 0.37 | .01 | 1.83 | .05 |
| Stage 4 (% ) | 22.60 (1.56) | 22.01 (2.05) | 0.05 | .00 | 0.55 | .02 | 23.16 (1.84) | 21.85 (1.51) | 0.30 | .01 | 0.80 | .02 |
| Light sleep (stages 1+2) | 49.49 (1.92) | 47.44 (2.53) | 0.38 | .01 | 2.88$^{+}$ | .08 | 48.55 (2.28) | 48.83 (1.89) | 0.01 | .00 | 2.46 | .07 |
| Slow wave sleep (stages 3+4) | 30.07 (1.73) | 31.05 (2.28) | 0.11 | .00 | 2.24 | .06 | 31.68 (2.03) | 29.59 (1.67) | 0.63 | .02 | 2.13 | .06 |
| REM (%) | 20.44 (0.90) | 21.51 (1.19) | 0.47 | .01 | 0.56 | .02 | 19.78 (1.04) | 21.57 (0.86) | 1.74 | .05 | 0.37 | .01 |

[a]Covariate means and standard deviations; Degrees of freedom: all 1.36; SOL=sleep onset latency; WASO=wakening after sleep onset; [b]a higher score corresponds to a higher level of sleep quality; [c]a higher score corresponds to higher level of insomnia; Groups of low and high PA levels are characterized by the recommendation of the Centers for Disease Control and Prevention (2002); ANOVA: . + $p<0.1$; *$p<0.05$; **$p<0.01$; ***$p=0.001$.

**Table 5.4**

Multiple linear regression models to describe the influence of self-reported and objective physical activity and gender on self-reported and objective sleep (*N* = 37)

| Dimension | Variables | Coeff. | Standard error | Coeff. ($\beta$) | 95% CI | *t* | *p* | *R* | $R^2$ | Durbin-Watson |
|---|---|---|---|---|---|---|---|---|---|---|
| **Self-reported sleep** | | | | | | | | | | |
| SOL (min) | **Self-reported PA** | 20.20 | 3.21 | --- | 13.77 to 26.64 | 6.30 | .000 | .276 | .076 | 1.77 |
| | Vigorous PA | -.002 | .001 | -.26 | -.01 to .000 | -1.90 | .064 | | | |
| | Gender | 5.94 | 4.18 | .20 | -2.44 to 14.33 | 1.42 | .161 | | | |
| | **Objective PA** | 20.37 | 3.29 | --- | 13.77 to 26.97 | 6.20 | .000 | .202 | .041 | 1.61 |
| | Moderate PA | -.10 | .07 | -.20 | -.24 to .04 | -1.43 | .160 | | | |
| | Gender | 2.41 | 4.02 | .09 | -5.66 to 10.47 | .60 | .552 | | | |
| WASO (min) | **Self-reported PA** | .85 | .21 | --- | .42 to 1.28 | 4.00 | .000 | .452 | .204 | 1.42 |
| | Vigorous PA | .000 | .000 | .25 | .000 to .000 | 2.00 | .057 | | | |
| | Gender | -1.00 | .28 | -.46 | -1.56 to -.44 | -3.58 | .001 | | | |
| | **Objective PA** | 1.08 | .24 | --- | .60 to 1.57 | 4.49 | .000 | .389 | .151 | 1.52 |
| | Moderate PA | -.002 | .01 | -.05 | -.01 to .01 | -.35 | .729 | | | |
| | Gender | -.83 | .29 | -.38 | -1.42 to -.28 | -2.83 | .007 | | | |
| Waking mood | **Self-reported PA** | 4.38 | .46 | --- | 3.46 to 5.30 | 9.54 | .000 | .075 | .006 | 1.75 |
| | Moderate PA | .000 | .000 | .07 | -.001 to .001 | .49 | .625 | | | |
| | Gender | -.17 | .57 | -.04 | -1.32 to .98 | -.30 | .767 | | | |
| | **Objective PA** | 4.46 | .48 | --- | 3.50 to 5.42 | 9.33 | .000 | .071 | .005 | 1.79 |
| | Moderate PA | -.01 | .01 | -.06 | -.03 to .02 | -.44 | .661 | | | |
| | Gender | .19 | .58 | .03 | -.02 to .04 | .32 | .748 | | | |
| Sleep quality | **Self-reported PA** | 4.67 | .37 | --- | 3.94 to 5.41 | 12.77 | .000 | .312 | .097 | 1.83 |
| | Moderate PA | .000 | .000 | .17 | .000 to .001 | 1.32 | .193 | | | |
| | Gender | .83 | .46 | .24 | -.09 to 1.75 | 1.82 | .075 | | | |
| | **Objective PA** | 5.02 | .40 | --- | 4.22 to 5.82 | 12.65 | .000 | .271 | .073 | 1.95 |
| | Moderate PA | -.01 | .01 | -.12 | -.02 to .01 | -.83 | .409 | | | |
| | Gender | .94 | .49 | .27 | -.03 to 1.91 | 1.94 | .058 | | | |
| ISI total score | **Self-reported PA** | 2.68 | .18 | --- | 2.31 to 3.05 | 14.59 | .000 | .391 | .153 | .28 |
| | Moderate PA | .000 | .000 | -.08 | .000 to .000 | -.59 | .558 | | | |
| | Gender | -.67 | .23 | -.37 | -1.13 to -.21 | -2.94 | .005 | | | |
| | **Objective PA** | 2.63 | .17 | --- | 2.28 to 2.97 | 15.28 | .000 | .431 | .186 | .32 |
| | Vigorous PA | .01 | .01 | .14 | -.01 to .02 | 1.08 | .299 | | | |
| | Gender | -.83 | .25 | -.45 | -1.32 to -.34 | -3.38 | .001 | | | |
| **Objective sleep** | | | | | | | | | | |
| SOL (min) | **Self-reported PA** | 10.02 | 2.08 | --- | 5.80 to 14.23 | 4.83 | .000 | .138 | .019 | 2.04 |
| | Vigorous PA | .000 | .001 | .07 | -.001 to .002 | .40 | .692 | | | |
| | Gender | -2.70 | 3.28 | -.15 | -9.35 to 3.96 | -.82 | .417 | | | |
| | **Objective PA** | 11.32 | 1.62 | --- | 8.02 to 14.62 | 6.97 | .000 | .295 | .087 | 2.39 |
| | Vigorous PA | -.15 | .09 | -.30 | -.33 to .02 | -1.83 | .077 | | | |
| WASO (min) | **Self-reported PA** | 12.94 | 5.84 | --- | 1.09 to 24.78 | 2.22 | .033 | .488 | .239 | 2.24 |
| | Moderate PA | .01 | .01 | .25 | -.002 to .02 | 1.64 | .109 | | | |
| | Gender | 20.66 | 8.87 | .36 | 2.66 to 38.67 | 2.33 | .026 | | | |
| | **Objective PA** | 19.84 | 5.67 | -- | 8.32 to 31.35 | 3.50 | .001 | .442 | .196 | 2.21 |
| | Vigorous PA | -.24 | .27 | -.14 | -.78 to .30 | -.91 | .370 | | | |
| | Gender | 25.87 | 9.09 | .44 | 7.39 to 44.34 | 2.85 | .007 | | | |
| Sleep efficiency | **Self-reported PA** | 95.89 | 1.35 | --- | 93.15 to 98.62 | 71.15 | .000 | .566 | .321 | 2.34 |
| | Moderate PA | -.002 | .001 | -.19 | -.004 to .001 | -1.33 | .194 | | | |
| | Gender | -6.86 | 2.05 | -.48 | -11.02 to -2.70 | -3.35 | .002 | | | |
| | **Objective PA** | 94.52 | 1.29 | --- | 91.90 to 97.14 | 73.33 | .000 | .535 | .306 | 2.33 |
| | Vigorous PA | .06 | .06 | .15 | -.06 to .18 | 1.01 | .318 | | | |
| | Gender | -7.97 | 2.07 | -.56 | -12.17 to -3.47 | -3.85 | .000 | | | |
| REM-latency | **Self-reported PA** | 94.91 | 7.78 | --- | 79.12 to 110.70 | 12.20 | .000 | .217 | .047 | 2.51 |
| | Vigorous PA | -.004 | .003 | -.21 | -.01 to .003 | -1.16 | .253 | | | |
| | Gender | 12.49 | 12.28 | .18 | -12.45 to 37.42 | 1.02 | .316 | | | |
| | **Objective PA** | 85.82 | 5.88 | --- | 73.88 to 97.77 | 14.59 | .000 | .396 | .157 | 2.54 |
| | Vigorous PA | .79 | .31 | .40 | .16 to 1.42 | 2.55 | .015 | | | |
| Stage 3 (%) | **Self-reported PA** | 7.80 | .85 | --- | 6.07 to 9.53 | 9.14 | .000 | .301 | .091 | 2.26 |
| | Moderate PA | -.001 | .001 | -.18 | -.003 to .001 | -1.09 | .285 | | | |
| | Gender | 2.28 | 1.30 | .29 | -.35 to 4.91 | 1.76 | .087 | | | |
| | **Objective PA** | 7.54 | .94 | --- | 5.64 to 9.45 | 8.04 | .000 | .237 | .056 | 2.22 |
| | Moderate PA | -.01 | .02 | -.04 | -.05 to .04 | -.23 | .817 | | | |
| | Gender | 1.84 | 1.30 | .24 | -.80 to 4.48 | 1.42 | .165 | | | |

*Note*: SOL= sleep onset latency; WASO = waking after sleep onset; Coeff. = Coefficient; *CI* = confidence interval; *R* = multiple correlation coefficient; $R^2$ = multiple coefficient of determination; gender code: female (0), male (1). Due to the intercorrelation of the variables (self-reported moderate and vigorous PA) separate regressions (stepwise backwards) were calculated using different combinations of predictors.

## DISCUSSION

The key findings of this study are that among Swiss adolescents attending vocational schools, higher levels of subjective and objective physical activity were related to more favorable subjective and objective sleep. Additionally, females were less physically active than males. Moreover, compared to objective PA, self-reported levels of physical activity seemed to be stronger predictors of sleep quality.

Five hypotheses were formulated and each of these will now be considered. First it was hypothesized that self-reported and objectively assessed physical activity would be correlated and this was confirmed. The results showed a weak (for moderate PA) to strong (for vigorous PA) correspondence between the International Physical Activity Questionnaire (IPAQ) and accelerometer data, confirming previous research [46, 47]. Nevertheless, our findings indicate that adolescents tend to overestimate their self-reported physical activity levels, especially their vigorous PA. The reason for overestimating vigorous physical activity may be e.g., bouts of high intensities during a 90 minute soccer-practice are reported as 90 minutes of vigorous PA, although vigorous physical activity is not performed during the entire period. Since accurate assessment of physical activity is crucial for defining recommendations for preventing and reducing sleep problems, we hold that our results make an important contribution to the body of literature regarding measurement methods [69].

The second hypothesis, was that self-reported and objectively assessed sleep patterns would be correlated. However, the relationships found in the present study were weak and inconclusive, a pattern consistent with previous research on adolescents [70] and adults [71]. With a mean of 19.2 minutes, SOL was self-rated almost twice as long as the objectively assessed latency of 9.7 minutes. Although males had shorter objective SOL than females, their self-perceptions far exceeded the females' reports. Research shows that many people with insomnia overestimate their SOL and underestimate their TST [e.g. 72, 73]. The findings are consistent with several studies reporting a discrepancy between subjective appreciation of insomnia symptoms and objective sleep measurements [74, 75]. This does not mean that insomnia is not a problem for these students, but that sleep-EEG may not be the best means to measure insomnia. According to the American Academy of Sleep Medicine, sleep-EEG is therefore not indicated for the routine evaluation of insomnia [76]. Again, this underlines the importance of using both subjective and objective measurements to assess the relationship between physical activity and sleep. However, even for normal sleepers the exact point of sleep onset is elusive. Adolescents in particular may report last night rather than average bedtime and/or socially desirable responses (e.g., later than the actual bedtime) [48]. As objective sleep data show (see Table 5.3), most adolescents slept less than they indicated, which points toward a general overestimation. In contrast, participants who report fair or poor mental health (e.g., depression, sleep deprivation) believe they have slept less than their actual sleep duration [71]. A further explanation for the poor correlation might be that self-reports in the present study referred to habitual sleep, whereas sleep-EEG devices measured the sleep pattern of one night. Lauderdale et al. [71] compared sleep variables collected from wrist actigraphy, sleep logs, and standard sleep questionnaires. Single-night estimates were only a little more accurate than the reports of habitual sleep. However, unlike eyes, which detect and process visual stimuli, we lack a specific organ or system that can detect or measure sleep quality. Therefore, choice of methodology to assess sleep patterns may be of great importance [48].

Hypotheses 3 and 4 predicted that higher levels of physical activity would be associated with more favorable sleep patterns and lower insomnia scores. The data supported the expectation that adolescents with self-reported physical activity levels above recommended thresholds tend to have longer TST, fewer WASO, fewer symptoms of insomnia, and better quality sleep. Considering that on average two thirds of MVPA occurred during PE classes, it seems likely that participation in PE plays an important role in the promotion of sleep among adolescents. However, high objective physical activity levels were less predictive of favorable sleep patterns than self-perception of PA. In support of hypothesis 3, participants with self-reported physical activity levels surpassing the recommended levels had significantly shorter self-reported SOL, independent of gender. But contrary to hypothesis 4, no such effects were found for objectively assessed PA. Again, this leads to several considerations regarding the methodological approach of studies that analyze the relationship of physical activity and sleep. Along with our findings, the majority of studies that have supported the beneficial influence of physical activity on sleep quality among healthy adolescents were based on self-reported physical activity and sleep [12, 41, 77, 78, 79]. Studies using accelerometers for assessing the relationship between objective physical activity and sleep patterns have often failed to show a convincing association [40-42]. Thus, the results of the present study confirm hypothesis 5 that a favorable association between physical activity and sleep might have less to do with actual behavior patterns than with individuals` self-perceptions about being physical active [21]. At first glance, this finding may appear contradictory, but with respect to cognitive models of insomnia, it emphasizes the relevance of cognitive processes, such as attention, perception, memory, reasoning, beliefs, attributions, and expectations, for the onset and maintenance of sleep complaints [52]. Because biological theories of a sleep-promoting impact are not sufficiently established, such paradoxical effects of physical activity are not uncommon, and they parallel findings of previous research [21, 80].

Additionally, not all studies have assessed frequency or intensity of PA. Instead, they often distinguish between sedentary and active adolescents [41], athletes and controls [12, 51, 77] or moderate [14] and vigorous exercise [23]. Regarding the optimal exercise intensity for a good night's sleep, our data suggest that vigorous physical activity tends to be a better predictor for favorable sleep patterns than moderate PA, whether the latter is assessed by self-reported or objective PA. Furthermore, the present study adds to the body of literature in which gender effects are examined as a possible confounding variable [81]. This is important, because female adolescents are at an increased risk of both sleep and affective disorders [82-84]. In our sample, female participants were less physically active compared to the males, suggesting a possible indirect influence of gender.

Various considerations, however, warn against over-generalizing the findings. First, the sample was based on adolescents who attended vocational schools in the German speaking part of Switzerland and are therefore not representative of the young adult Swiss population. Second, one could argue that the majority of our sample qualified as healthy sleepers and clearer effects of physical activity might have been observed in a sample of individuals with insomnia [14, 85]. Third, for female participants, menstrual cycle phase - interacting with circadian processes [86] - was not documented. Therefore, it is also conceivable that the observed gender differences in sleep architecture and reported insomnia symptoms were influenced by menstrual cycle and contraceptive intake. Fourth, findings were based on cross-sectional data, precluding a causal interpretation. Fifth, due to insufficient accelerometer- and EEG-recordings, we had a relatively small sample size. Last, future research on physical activity and sleep should take further psychological factors into account to determine whether the sleep-promoting effect of physical activity is moderated via cognitive processes.

## CONCLUSION

In the present study we were able to show that greater physical activity was favorably associated with restoring sleep. The major strength of this investigation is the combination of both self-report and objective measurements in a single sample of adolescents. Our findings emphasize that choice of methodology to examine the relationship between physical activity and sleep may be of great importance.

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# CHAPTER 6

## Teaching stress management in physical education: A quasi-experimental study with vocational students (EPHECT I).

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# TEACHING STRESS MANAGEMENT IN PHYSICAL EDUCATION CLASS: A QUASI-EXPERIMENTAL STUDY WITH VOCATIONAL STUDENTS (EPHECT I).


## ABSTRACT

*Objectives:* To develop, implement and evaluate a physical education-based coping training (EPHECT) for vocational students.
Design: Quasi-experimental study.

*Methods:* One school received the EPHECT intervention (IG n = 434), while the other school maintained regular PE (CG n = 430). Repeated measures ANCOVAs were used to examine the effects on coping and perceived stress. Additionally, effects were compared among students who perceived low versus elevated life satisfaction. Finally, implementation rate was considered as a moderating factor.

*Results:* Overall, no significant time by group effects were found between the IG and CG. However, a reduction in maladaptive coping occurred among students of the IG who reported low life satisfaction. The implementation rate did not moderate the findings.

*Conclusion:* Despite a relatively low implementation rate, EPHECT reduced maladaptive coping strategies in adolescents with low life satisfaction. Program monitoring needs to be increased in future research.


**Key words:** Adolescents, Coping, Physical Education, Implementation Fidelity, Mental Health, Satisfaction with Life

## INTRODUCTION

Stark increases in adolescent stress and its accompanying negative consequences has resulted in governments increasingly looking to schools as an ideal setting for promoting resilience. Resilience is defined as the ability to recover from or adjust easily to adversity or change [1]. However, although improving stress management skills figures among adolescents' most required health needs [2], only one third of German students were interested in participating in a stress management training program [3] . A general good health perception [4] and fear of stigmatization [5,6] might be reasons for their lacking interest in health prevention programs. Shochet and colleagues [7] argue that stigmas are the main reasons for participant recruitment difficulties and high dropout rates. Therefore, they recommend universally applied programs within the context of regular school classes that include all students, independent of the actual risk of mental disorder. Given that PE is generally recognized as a suitable subject within the school curriculum to promote both physical and mental health [8,9], some scholars argue that PE can be used to transmit important life skills and health-related knowledge (e.g., [9]). However, although preliminary evidence exists that PE can bring relief from school stress [10], no attempts have been made so far to purposefully teach stress management skills in PE. This is surprising given the unique features of PE, which allow for the provision of authentic learning experiences by linking theory and practice, and by enabling students to experiment with coping strategies in the face of real physical and psychosocial stressors [12].

Therefore, the purpose of the present study was threefold. Our first goal was to develop, implement and evaluate the effectiveness of a PE based coping training (entitled: EPHECT) for students in vocational education and training. As previous studies provided evidence for the effectiveness of school-based stress management programs [13], we hypothesized that students of the intervention group (IG) would improve their coping skills more than peers of the control group (CG) (Hypothesis 1a). We also expected favorable effects on perceived stress among students participating in the EPHECT intervention (Hypothesis 1b). Our second goal was to find out whether EPHECT has particular positive effects among students who presumably benefit most from school health prevention programs such as students with relatively low life satisfaction [14]. Based on previous literature, it was hypothesized that greater improvements will occur among these students because they might be more interested in and show greater compliance with the program [6,3] . Third, we wanted to examine whether the effectiveness of the intervention program depends on the degree of implementation fidelity. Based on previous research, we expected the strongest effects in classes with high implementation fidelity, independent of whether students report low or elevated life satisfaction [15,16].

## METHOD

### Participants and procedure

A sample of 864 students ($M_{\text{age}}$ = 17.87, *SD* = 1.32, 43% females) attending two VET schools in German speaking Switzerland participated in this quasi-experimental study. The EPHECT intervention was implemented within regular PE lessons in one school, which served as IG (*n* = 434, 45% females). The second school served as CG and received conventional PE without intervention (*n* = 430, 40% females). Each of the nine PE teachers (4 males, 5 females) who implemented the intervention taught three classes or more.

To determine the effectiveness of the 8-month EPHECT intervention, all students completed pre- (September) and post-intervention (May) questionnaires related to coping strategies and perceived stress. Students were informed that filling in the questionnaire is voluntary and that responses are anonymous. A trained research assistant was present while students filled in the questionnaire. The study was approved by the local ethics committee and was performed according to the ethical standards in the Declaration of Helsinki.

## Intervention materials

EPHECT consisted of eight modules, which were sequentially implemented by the PE teacher during PE class. The first module addressed basic knowledge about the nature, development and regulation of stress. The next seven modules focused on the promotion of emotion- and problem-focused coping skills, including functional and dysfunctional thinking styles, problem solving, social support seeking, and relaxation techniques (for a more detailed module description see www.ephect.unibas.ch).

Drawing on experiential learning theory [17], EPHECT was designed to allow learning via practical experiences in PE about stress. The main idea was to enrich motor skill training with learning about stress-related matters. Overall, the implementation of each module required approximately 20 minutes, and following completion, the teacher briefly discussed with the students (a) how the tasks relate to the regulation of stress, and (b) what can be learned from these experiences for coping with everyday stressors (e.g., arguments with family members, pressures from peers, occupational demands).

To facilitate the transmission of theoretical knowledge and to maintain high levels of physical activity during PE, all students received the EPHECT workbook, which they completed as homework. The workbook contained eight chapters (each corresponding to a module), which all started with a short story to catch students' attention, followed by a summary of the most important theoretical information, self-tests, and reflection tasks. The reflection tasks aimed at stimulating a transfer of learning from the gymnasium to everyday life. To standardize intervention delivery, each teacher received the EPHECT teacher manual containing detailed module descriptions. Moreover, each teacher of the intervention school took part in 2.5-day teacher-training workshop prior to the start of the intervention.

## Measures

*Socio-demographic background*

Students reported their sex, age, body weight and height, and their family financial situation (as compared to peers) on a 5-point scale (1 = much worse, 5 = much better). Body weight and height (kg/m$^2$) were used to calculate BMI.

*Coping skills*

Coping skills were assessed using the Coping Questionnaire for Children and Adolescents [18]. Answers were given on a 5-point Likert scale from 0 (not at all) to 4 (every time). Higher sum scores represented a stronger tendency to use a particular coping strategy. Information about sub-dimensions, sample items and Cronbach's alphas are presented in Table 1 (as for all outcome variables).

*Perceived stress*

Perceived stress was assessed with the 30-item Adolescents Stress Questionnaire short form [19]. The short form uses those three items with the highest factor loadings per subscale [20]. Each item was rated on a 5-point Likert scale ranging from 1 (not at all stressful) to 5 (very stressful). Items were summed up to build an overall index, with higher scores reflecting higher stress.

*Life satisfaction*

Life satisfaction was assessed with 3 items of the Satisfaction with Life Scale [21]. Each item was rated on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Higher mean scores are indicative for higher life satisfaction.

*Implementation fidelity.*

Teachers answered six items to rate implementation fidelity for each class. In line with Dane and Schneider [22], teachers recorded the depth of program delivery (e.g. "I implemented all modules with this class."), the quality of program implementation (e.g. "I think the students in this class have increased their knowledge about coping with stress.") and the perceived responsiveness of the students (e.g. "The students have worked with the workbooks"). Answers were given on a 4-point scale ranging from 1 (not at all) to 4 (very much). Items were summed up to obtain an implementation index, with higher scores reflecting greater implementation (Cronbach's $\alpha = .87$).

**Statistical analysis**

Students were clustered according to class, thus nested datasets required multi-level modelling when significant variation in response variable scores were present [23]. The intra-class correlations (ICCs) indicated that class affiliation had no effect on the main outcome variables before and after the intervention (Table 1). Thus, to assess possible interaction effects of the EPHECT intervention on coping and stress perception, 2 x 2 repeated measures ANCOVAs with time (pre vs. post) and group (IG vs. CG) as fixed factors were executed. A series of 2 (pre vs. post) x 2 (IG vs CG) x 2 (low vs. elevated life satisfaction) repeated measures ANCOVAs were carried out to compare the effectiveness of the intervention in students with low (scores $< 4$) versus elevated life satisfaction (scores $\geq 4$). Finally, in intervention classes, 2 (pre vs. post) x 2 (low vs. elevated life satisfaction) x 2 (low-to-moderate vs. moderate-to-high implementation) ANCOVAs were performed to find out whether implementation fidelity had an impact on program effectiveness. Sex, age, BMI, and family financial situation were used as covariates in all ANCOVAs. Implementation was considered low-to-moderate if scores ranged from 1 to 2.5 ($n$ = 23 classes: $n$ = 224 students, 119 females, 105 males) and moderate-to-high if scores varied between 2.51 – 4 (*n* = 10 classes: *n* = 130 students, 71 females, 59 males). Teacher evaluation questionnaires were missing from nine classes (*n* = 80 students). However, these students did not differ in socio-demographic background and the outcome variables when compared to the remaining 354 peers of the IG.

## RESULTS

### Descriptive statistics and psychometric properties

Table 1 represents means, standard deviations, ranges, skewness, kurtosis, Cronbach`s α coefficients, intra-class correlations (ICC), and sample sizes for all psychological variables.

**Table 6.1**

Means, standard deviations, Cronbach's α coefficients, intra-class correlations (ICC), range, skweness, kurtosis, and sample size for each study variable

| | *Stress* | | *Coping* | | | | | | *Life Satisfaction* |
|---|---|---|---|---|---|---|---|---|---|
| | | | *Adaptive coping* | | | | *Maladaptive coping* | | |
| | | | *Emotion-focused* | | *Problem-focused* | | | | |
| | *t1* | *t2* | *t1* | *t2* | *t1* | *t2* | *t1* | *t2* | *t1* |
| *α* | .86 | .88 | .64 | .66 | .78 | .75 | .83 | .85 | *.78* |
| *ICC* | .069 | .043 | .019 | .008 | .036 | .058 | .069 | .017 | --- |
| *M* | 6.95 | 6.91 | 5.02 | 5.19 | 7.09 | 6.93 | 5.74 | 5.57 | *4.89* |
| *SD* | 1.80 | 2.00 | 1.96 | 2.01 | 2.07 | 2.00 | 2.10 | 2.15 | *1.14* |
| *Possible range* | 0-120 | 0-120 | 0-12 | 0-12 | 0-12 | 0-12 | 0-12 | 0-12 | 1-7 |
| *Actual range* | 3.00-12.2 | 3.00-13.90 | 0-12 | 0-12 | 0-12 | 0-12 | 0-12 | 0-12 | 1-7 |
| *Skewness* | 0.26 | 0.35 | -0.12 | 0.10 | -0.54 | -0.36 | -0.03 | 0.11 | -0.63 |
| *Kurtosis* | -0.53 | -0.26 | 0.07 | 0.46 | 0.89 | 0.42 | 0.05 | -0.07 | 0.19 |
| *N* | 864 | 864 | 864 | 864 | 864 | 864 | 864 | 864 | *864* |

*Note.* Stress = Adolescent Stress Questionnaire (e.g., "Teachers expecting to much from you"); Coping = Coping Questionnaire for Children and Adolescents (adaptive coping: emotion-focused coping consisted of 3 items from two subscales: distraction and reframing: e.g., "I say to myself: That's not so tragic."; problem-focused coping consisting of 3 items from three subscales: support seeking, positive self-instruction and situation control: e.g., "I try to figure out what the problem is.", maladaptive coping items consisting of 3 items from four subscales: rumination, resignation, aggression and behavioral avoidance: e.g., "I prefer skirting an issue."). Life satisfaction = Satisfaction with Life scale (3 items: e.g., "I am satisfied with my life.").

### Baseline group differences

No significant differences between the IG and CG were observed at baseline for age, BMI, and family financial situation. Likewise, no significant differences existed between the IG and CG in coping and perceived stress (all *p*s > .05). Furthermore, the sex distribution was similar in the IG and CG, $Chi^2(1,864) = 1.58$, $p$ = ns.

**Changes in coping and stress across time in the IG and CG**

Table 2 provides time by group effects with coping and stress as independent variables. No statistically significant main effects for time and group were observed for any of the outcomes. Furthermore, none of the two-way interaction terms was significant. Thus, against Hypothesis 1a and 1b, these preliminary analyses suggest that (overall) the EPHECT program was not able to positively impact on students' coping skills and stress perceptions.

**Changes in coping and stress depending on baseline life satisfaction**

Nevertheless, Table 2 shows that Hypothesis 2 was partly supported. Thus, the results of the repeated-measures ANOVA yielded a significant three-way interaction for maladaptive coping. As illustrated in Figure 1, students with low life satisfaction scored highest on maladaptive coping at baseline. In this group, however, scores decreased significantly in students who participated in the intervention program, whereas they remained stable in the CG. No significant three-way interactions were found for the other outcome variables.

**Changes in coping and stress depending on implementation fidelity**

In total, 63% of all teachers reported that the overall implementation fidelity was low-to-moderate (scores from 1 to 2.5), while 37% reported moderate-to-high implementation fidelity rates (scores from 2.5 to 3.49). A high implementation rate (≥ 3.5) was reported for none of the classes. Nevertheless, as shown in Table 2, implementation fidelity did not moderate the findings. Thus, while the significant two-way interaction remained for maladaptive coping, no significant three-way interactions occurred.

**DISCUSSION**

The main aim of this study was to develop a PE-based coping training for VET-students and to determine if PE teachers can teach coping skills in the PE setting. The key finding is that the EPHECT intervention resulted in decreased maladaptive coping in students with initially low levels of life satisfaction. With regard to adaptive coping and perceived stress, no significant time by group effect was found.

Taken together, three hypotheses were tested. Our first hypothesis was not confirmed. Thus, compared to the CG, the IG did not improve their coping skills or reduce their stress perceptions from pre- to post-intervention. While this supports reviews showing that sometimes whole-school approaches to promote mental health fail or have negligible impact [24,25], the lacking overall effectiveness can be attributed to at least five additional reasons:

**Table 6.2**
Inferential statistics for time (pre- vs. post intervention), group (IG vs. CG), life satisfaction (low vs. higher), implementation rate (low-to-moderate vs. moderate-to-high); $N$ = 784

| | Hypothesis 1 | | | | | | Hypothesis 2[a] | | | | | | Hypothesis 3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Time | | Group | | Group x time | | Time | | Time x LS | | Time x Group x LS | | Time | | Time x LS | | Time x LS x IF | |
| Variables | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ |
| Adaptive coping | 0.73 | .001 | 0.26 | .001 | 0.02 | .000 | 0.85 | .001 | 1.19 | .001 | 0.09 | .000 | 0.09 | .000 | 0.19 | .001 | 0.02 | .000 |
| Emotion-focused coping | 0.05 | .000 | 0.12 | .000 | 0.23 | .000 | 0.05 | .000 | 0.01 | .000 | 0.36 | .000 | 0.12 | .000 | 0.04 | .000 | 1.98 | .006 |
| Problem-focused coping | 1.07 | .001 | 2.97 | .003 | 0.27 | .000 | 1.28 | .001 | 2.10 | .002 | 0.00 | .000 | 0.50 | .001 | 0.61 | .002 | 1.51 | .004 |
| Maladaptive coping | 0.07 | .000 | 0.13 | .000 | 0.01 | .000 | 0.11 | .000 | 2.29 | .003 | 11.05** | .013 | 0.03 | .000 | 9.96** | .028 | 1.54 | .004 |
| Perceived stress | 1.50 | .002 | 0.29 | .000 | 1.42 | .002 | 1.93 | .002 | 6.34* | .007 | 0.97 | .001 | 0.88 | .003 | 2.64 | .008 | 0.59 | .002 |

*Note.* Covariates: Age, sex, BMI, family financial situation. Group: IG vs. CG. LS = Life satisfaction: Low vs. higher life satisfaction. IF = Implementation fidelity: Low-to-moderate vs. moderate-to-high implementation fidelity. [a]Main effects for group and LS, and two-way interaction between Time x Group not shown because all results were non-significant. [b]Main effects for LS and IF, and two-way interaction between Time x IF not shown because all results were non-significant. *$p$ < .05. **$p$ < .01 ***$p$ < .001

First, the program might have been too short or not intensive enough. Second, EPHECT was taught by PE teachers, whereas previous school based stress management program were conducted by psychologists (e.g., [13]). Third, the program's effectiveness may depend on characteristics of the students. For instance, Weare and Nind [14]assumed a "ceiling effects in populations without overt problems not having the same scope for improvement" (p. 59). Accordingly, Calear and Christensen [26] found that school-based depression programs are most effective if the targeted students exhibiting elevated levels of depression. A similar finding was found in the present study. Thus, in support of Hypothesis 2, students with low life satisfaction profited most from the intervention program. However, improvements were only found for maladaptive coping, whereas adaptive coping and perceived stress were unaffected. As suggested by Giebink and McKenzie [28], it might be easier to stop inappropriate behavior tendencies than learning and establishing new and adaptive ones. Moreover, stress is a rather distal outcome that might depend on many factors outside the scope of the EPHECT intervention (e.g., work environment, family climate, relationship with peers) [28]. Notwithstanding the above, reducing maladaptive coping strategies is an important endeavor among adolescents because compared to healthy controls, people diagnosed with depression more often report dysfunctional coping strategies such as avoidance and denial [29]. Moreover, maladaptive coping strategies constitute a significant risk factor in the development of adolescent depression [30], and are closely associated with self-harm [31].

Third, one can speculate that the effectiveness of the intervention strongly depends on the degree of intervention fidelity. Correspondingly, several reviews have shown that implementation fidelity can affect the success of an intervention [15,16], and that weakened results or even negative side effects may arise if programs are not implemented as intended [32]. Although in the present study implementation fidelity did not moderate the findings (as expected in Hypothesis 3), we point to the fact that the overall implementation rate was relatively low. Hence, a high implementation rate was not found in any of the classes. Moreover, despite the fact that 83% of the teachers indicated that they have implemented all or almost all of the EPHECT modules, and that 70% of the students worked with the booklet at least to some extent, teachers also stated that only 3% of the students completed all required readings, self-tests and reflection tasks. Wilson and Lipsey [25] attribute the low impact of whole-school programs to a low motivation level of teachers, which leads to poor student compliance. Thus, finding ways to intensify teacher training, to increase teachers' motivation, to improve monitoring of program delivery, or to perform homework control might be desirable approaches to increase program effectiveness that should be tested in future research [33]. In summary, we acknowledge that poor adherence to the EPHECT protocol by the PE teachers was a major limitation of the study, particularly as reflection assignments are a core element of EPHECT, which should be initiated in conjunction with the workbook exercises.

## CONCLUSION

This study aimed at developing, implementing and evaluating a PE based coping training among VET-students. The fact that students with low life satisfaction reduced maladaptive coping strategies from baseline to post-intervention was a promising finding. However, conclusions are currently limited by several factors relating to unsatisfactory teacher compliance. Therefore, improved monitoring of implementation fidelity is identified as a key issue, which needs to be addressed to gauge the full potential of the EPHECT intervention.

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# CHAPTER 7

## Effects of a physical education-based coping training on adolescents` coping skills, stress perceptions and quality of sleep (EPHECT II).

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# EFFECTS OF A PHYSICAL EDUCATION-BASED COPING TRAINING ON ADOLESCENTS` COPING SKILLS, STRESS PERCEPTIONS AND QUALITY OF SLEEP (EPHECT II)


## ABSTRACT

*Background:* Although most adolescents successfully manage the transition between childhood and adulthood, the speed and magnitude of these changes may exceed the coping abilities of a significant number of young people. For vocational students, additional responsibilities arise during the vocational school transition and the need to balance academic and job-related requirements. An expanding body of literature suggests that adolescence is a vulnerable period for the development of psychiatric diseases and as such, the need to develop an adequate coping repertoire is receiving increasing attention globally. The growing awareness of long-term consequences of stress has led governments to instill school-based resilience promotion programs. For instance, the new PE curriculum of vocational (VET) students in Switzerland addresses stress management, because stress-related diseases at the workplace have become commonplace among young professionals.

*Purpose:* Our aim was to develop, implement and evaluate a PE-based coping training (EPHECT) for VET students. Therefore, we adapted components of extant field-tested coping training programs and tailored them to the unique needs of VET students. To facilitate the standardization of the program, each teacher received a teaching manual. Moreover, drawing upon experiential learning theory, we introduced the contents of the coping training in PE class through practical, movement-based exercises in PE. Students also received a workbook for use at home.

*Participants and Research Design:* In this cluster randomized controlled trial, eight classes from a Swiss vocational school participated ($N$ = 131, $M_{age}$ = 16.22 ±1.12, 35% females). Two trained PE teachers implemented the program with students in the intervention group (IG = 67) for three months, while students in the other four classes maintained regular PE (CG = 64) to comprise the control group. To evaluate the coping training, all participants completed several self-report psychological questionnaires (assessing stress, coping and sleep) at baseline and follow-up. IG students completed further questions with regards to intervention fidelity at follow-up.

*Data analysis:* To evaluate possible effects of the coping training on stress, coping and sleep, a 2 x 2 repeated measures ANOVA design was executed with time (pre vs. post) and group (IG vs. CG) as within- and between-subject factors.

*Findings:* Over time, IG students significantly increased their adaptive coping compared to CG students, while stress and sleep remained relatively stable for both. Regularly completing one's homework reinforced this effect because it was significantly associated with students' reflection and compliance.

*Conclusion:* A complete and accurate implementation of a PE-based coping training can make a positive contribution to the development of adaptive coping skills among adolescents attending vocational schools. This PE-based program allows students to experience their responses to stress directly and offers opportunities to experiment with different coping strategies. Adaptive coping skills are vital for successful stress management and the prevention of stress-related disorders across the work domain and in everyday life.

**Keywords:** Adolescents, coping, physical education, sleep, stress management

## INTRODUCTION

The speed and magnitude of changes during adolescence and the transition to a vocational school may potentially exceed the coping abilities of young employees [1–3]. Coping is understood here as the ability to solve personal problems, and to master, minimize or tolerate stress or conflicts [4,5]. In general, adolescents may experience difficulties, such as family relationships, school performance, interpersonal relationships and financial constraints [6]. For vocational students, additional responsibilities arise from the transition to a vocational school and the need to balance academic and job-related requirements [7]. A national study with Swiss adolescents showed that improved skills in dealing with negative emotions, stressful situations and sleeping problems are the most frequently requested health skills by young people [8]. These findings highlight that a considerable proportion of adolescents appears to have problems coping with developmental tasks [9–11] and corroborate the notion that adolescents' confidence in their ability to cope decreases during adolescence [12].

A lack of adequate coping strategies among young professionals may cause, sustain and exacerbate sleep disturbances [13,14], which, in turn increases stress [15]. Due to the important role of sleep as a moderator of the relationship between stress and health [16,17], research draws increased attention to the dramatic maturational sleep changes in adolescence [18]. However, sleep disturbances may also result from high stress levels [16]. Diary studies have demonstrated that daily stress is associated with poorer sleep [19,20]. Prospective epidemiological studies suggest that impaired sleep increases the risk for depressive disorders [21,22] and may facilitate the development of somatic complaints, poor academic achievement and poor psychological well-being [18]. Recent findings in Swiss vocational students highlight that one-third of these working adolescents experience mild school- and job-related burnout symptoms, whereas 16% show strong and 7% clinically relevant burnout symptoms [23]. Bearing in mind that adolescence is a period when many life habits are established, there is a need for prevention programs to target adolescent health and, in particular, the development of coping skills [3] and proper sleep hygiene [24].

**Stress prevention among vocational students**

Despite these insights, research on the relationship between stress, coping and sleep among adolescents and vocational students is scarce. In countries such as in Switzerland, Austria, and Germany, vocational education and training (VET) is an important component of the education systems and serves as the primary gateway to numerous occupations. The majority of all secondary school diplomas in Switzerland (74%) are granted to students with VET [25]. Swiss VET combines apprenticeships within the company of employment (3-4 days/week) and simultaneous vocational training at school (1-2 days/week). During this time, VET students serve as apprentices and receive a stipend for their work in the company, but they often have workloads similar to adult employees [26]. The VET systems in other parts of Europe are similar to that of Switzerland, with a general acceptance of VET qualifications across borders [27].

As emphasized by cognitive-transactional stress models [28,29], among other constructs, stressful life circumstances constitute a risk to health. Specifically, several appraisal processes and the availability of skills and resources to cope with stress create an impact on the stress-coping process. Therefore, embracing a broad and balanced repertoire of adaptive or constructive coping skills is key to fostering resilience (ability to recover from or adjust easily to misfortune or change) [30].

Consequently, to translate psychological theory into practice, several school-based intervention programs have been developed to promote adolescent coping skills [31–35]. These programs predominantly foster emotion- and problem-focused coping skills and are taught by psychologists or trained personnel. For instance, the SNAKE-program [31] consists of four modules implemented in eight, 90-minute units within a classroom setting. While in the first module, basic knowledge regarding stress and problem solving is conveyed, the following three optional modules are focused on cognitive reframing, seeking social support, relaxation and time management. Outcome variables included knowledge about stress and coping, coping strategies and perceived stress vulnerability. Results within different populations of adolescents (varying in age, gender and school type) demonstrate that (a) the programs were successful in increasing stress-based knowledge and (b) they had small, but positive effects on adolescents' adaptive coping skills [32,35–37]. Congruently, the meta-analysis of Kraag et al. [38] showed that school programs targeting stress management and coping are effective in reducing stress symptoms and enhancing coping skills.

**Promoting life skills in PE**

The majority of school-based coping programs [32,35–37] are based on educational theories about stress and coping in a classroom setting. Life skills programs taught in the normal classroom bear the risk that students receive the program as yet another part of compulsory education. However, offering programs in the PE setting has the potential to seamlessly integrate theory with practical experiences of stress by introducing challenging tasks that replicate stressful situations (e.g., two-versus-one game situations). This practical approach incorporates the idea of experiential learning, in which the learning process occurs through action and reflection on “doing” [39]. When transferred to coping training, if students get confronted with stressful or seemingly unsolvable tasks during PE, they need to apply appropriate coping skills. With a short reflection period after completing the tasks, the experiences of adaptive and maladaptive coping (e.g., positive vs. negative self-talk) can be discussed to reinforce practical applications. Furthermore, reflecting on students’ individual stress responses could be a method of increasing mental health awareness in students.

The idea that PE not only promotes motor learning, but also contributes to the development of life skills has a long history [40,41]. Pühse and Gerber [40] summarize in their comparison of cross-national PE-curricula that health education is a core element in most countries. Recently, Thorburn, Jess, and Atencio [42] have added that, akin to other countries (England, New Zealand), policy innovations in Scotland connect PE with health and well-being to an even greater extent. In Switzerland, the new PE curriculum of vocational students explicitly addresses stress management as one of its core elements [43]. This curriculum comes as a consequence of national health surveys [7] showing that stress-related diseases in the workplace are prevalent among young professionals in Switzerland. Despite the fact that the promotion of health and well-being are increasing within PE curricula, it is rarely addressed in physical educator training [44]. This situation persists in spite of the fact that PE provides an excellent framework to implement such life skills in step with actual practice.

Thus, in summary, an appropriate intervention that concentrates on adolescent vocational students, and shows physical educators how to address such life skills in PE, has yet to be conducted.

**Rationale and hypotheses**

Considering this background, the purpose of the present study was twofold. First, to develop a PE-based coping training for adolescent vocational students, drawing on theoretical frameworks and empirically tested coping training programs e.g. [31]

The second purpose was to evaluate the program’s effectiveness related to changes of (a) perceived coping skills, (b) stress perception and (c) sleep quality. Thus, we focused on a direct comparison between the intervention and control groups. We hypothesized that the coping training would result in moderate improvements regarding adolescents’ self-reported coping skills as the most proximal outcome [36,37,45,46] (Hypothesis 1). Specifically, we assumed that the coping training would promote adaptive coping, while reducing maladaptive coping strategies. This assumption is based on previous cognitive-behavioral research results which showed increased adaptive and decreased maladaptive coping scores [37,45]. We also expected that the intervention program would lead to reduced stress perceptions (Hypothesis 2) and increased subjective quality of sleep (Hypothesis 3).

## METHOD

### Participants and procedure

A total of 131 first year students from eight classes of a vocational school in central German-speaking Switzerland participated in this cluster randomized controlled trial ($M_{age}$ = 16.22, *SD* = 1.12, 35.2 % females). The school comprised 1189 students allocated into 70 classes, which all participated in PE lessons once per week (either 45 or 90 minutes/week). Occupational training for the following professionals was offered at this school; polytechnicians, retail assistants, industrial clerks, structural draftsmen and hairdressers. PE lessons were taught by six PE teachers (5 males, 1 female). Five of the teachers were highly motivated to volunteer for implementing the EPHECT intervention (4 males, one female). Of the five, we randomly selected two teachers to participate in this study (2 males, $M_{age}$ = 40.50, *SD* = 9.89). Two classes from each teacher (four classes total) were randomly assigned to the EPHECT intervention (intervention group: IG, $n$ = 67; $M_{age}$ = 15.96, *SD* = 1.04, 32.4 % females). The other four classes (control group: CG, $n$=64; $M_{age}$ = 16.44, *SD* = 1.09, 31.7 % females) participated in conventional PE lessons and were not informed about the intervention. To minimize the likelihood that students in the coping program would talk about the specific contents of the program to students in the control condition, the randomization involved the allocation of classes, which did not attend school on the same day.

The program was executed every week (excluding vacation) between August 2012 and November 2012 and was included as part of students' regular PE class. To evaluate the 3-month EPHECT intervention on coping, stress and sleep, all students completed two series of questionnaires related to socio-economic background, perceived stress, coping strategies and quality of sleep. Baseline data were collected in August 2012, follow-up data were collected in November 2012. Complete baseline and follow-up data were available from 122 students (IG $n$ = 63; CG $n$ = 59). In total, there was a 7% dropout rate from baseline to follow-up (authorized absence of PE lesson on assessment day). Analysis revealed significant differences for age and perceived stress. With regard to age, incomplete data were more common among older students, $F(1,130) = 4.23$, $p < .05$, $\eta^2 = .032$. Dropouts also reported higher stress scores than completers, $F(1,130) = 4.69$, $p < .05$, $\eta^2 = .035$. However, an intention-to-treat analysis (last observation carried forward = LOCF) did not show a different trend for non-completers from baseline to post-intervention.[1] Among the final sample, no

[1] The intention-to-treat analysis is a common technique used in randomized controlled trials, where the final results of participants are compared within their allocated group, independently of having dropped out of the study. The LOCF is a standard method in handling such missing data by simply imputing the last existing data, assuming the last observation is a valid representation of the final stable response distribution. It allows examining trends over time, if participants were lost to follow up for reasons other than non-compliance (Carpenter & Kenward, 2008).

significant baseline differences between IG and CG students were observed for age, gender, BMI, and family financial situation.

All participants completed the questionnaires during class hours in the presence of a trained research assistant. Participants received detailed information about the purpose of the study and the voluntary nature of their participation. They were assured confidentiality and provided informed written consent prior to completing the questionnaires. Parents' informed consent was required for participants under 18 years old. The study was approved by the local ethics committee and was performed according to the ethical standards in the Declaration of Helsinki.

**Intervention**

The intervention program was derived from a series of field-tested stress management programs [31,33,34,47–49]. Components of these programs were adapted and tailored toward the specific professional situation of VET students managing the dual burden of academic and work-related requirements. The systematic and research-based development and optimization process occurred in close collaboration with experienced PE teachers at vocational schools, as well as experts from sports science, sport and exercise psychology, and child and youth psychiatry. Drawing on the experiential learning theory of Kolb [39], we introduced the coping training in PE class. The intention was to create concrete situations for the individual students or the group as a whole, which could be reflected on afterwards (e.g. to address awareness for potentially stress-accelerating mental states, problem-solving skills and relaxation techniques) (see Table 7.1). In addition to the previous reflection phase, the homework tasks in the workbook demonstrate possible coping strategies and encourage students to experiment with these strategies within their daily routine. Via a practice log in the workbook, students can plan and document their attempts.

EPHECT consists of eight modules, each implemented in individual PE lessons. All intervention classes received the same program. The same sport activities were taught to the students of the control group, but without referring to the stress management. Module 1 addresses basic knowledge about the development of stress. The following six modules focus on various aspects related to emotion- and problem-focused coping. Module 2 raises awareness about dysfunctional and potentially stress-accelerating mental states. Module 3 aims at improving problem solving skills. Module 4 addresses positive thinking styles (e.g., reframing, positive self-talk). In Module 5, the students practice specific relaxation techniques including progressive muscle relaxation and breathing exercises. This module also aims at improving sleep hygiene. Module 6 addresses successful help seeking. Module 7 promotes behavioral skills, including action planning, time management and the capacity to deal with behavioral barriers. Finally, Module 8 is designed as a closing event, in which the students apply the learned contents (a detailed description of the modules is provided on www.ephect.unibas.ch).

Each regular 90-minute PE class contains 20 minutes of EPHECT. All EPHECT tasks were linked with one or several motor learning tasks, followed by a short reflection period moderated by the PE teacher. To limit the time necessary for deepening theoretical inputs in regular PE, each student received an EPHECT workbook, in which exercises were assigned for homework. The workbook reflection tasks encouraged the students to transfer their experiences obtained in PE to other domains of life. For example, a problem-solving task such as, "cross the gym without touching the ground" was conducted during a PE lesson. The reflection task for homework provided typical workplace problems, which could be resolved by using the problem-solving cycle learned in PE. Students can further document their experiences of implementing a new coping strategy in their everyday life. Thus, the workbook also functions as a progress portfolio for the student. Students were encouraged to ask for guidance from the teacher, but teachers were not recommended to grade the workbook.

To keep the teacher workload low and to facilitate the standardization of the program, each teacher received an EPHECT manual in which every module was described in detail (theoretical background, learning targets, exercise tasks, example lessons, instructions on how to guide the reflection). To further train teachers, two half-day workshops were provided with theoretical (e.g. stress model) and practical contents (during which every module was run through). Additionally, to obtain information regarding the degree of program implementation within each class, a member of the investigation team passively observed every PE lesson during the intervention, using a standardized observation form (see below).

**Table 7.1**
Description of the EPHECT coping intervention modules

| Aims of module | Movement tasks and reflection in PE class | Homework / Workbook |
|---|---|---|
| **1. Experience and understand stress**<br>*A. Stress is individual:* The students should understand that the same situation can lead to different perceptions and reactions in different people.<br>*B. Be aware of stress:* The students' sensitivity to their own stress reaction should be increased.<br>*C. Pay attention to warning signals:* In order to prevent chronic stress, it is important to listen to warning signals of the body (headache, fatigue, back pain) and to know when it is time for a break or change. | Challenging tasks for the individual student, e.g., John has no fear of falling backwards from ten box sections on a mat, but feels extremely uncomfortable crawling through a tunnel of mats, unlike Luke. Reflection: How did students feel they were stressed? (e.g., sweaty hands, shaking, fast heartbeat, sore stomach, headache)?<br>Did students experience similar feelings in everyday life? | • Read background on development and consequences of stress<br>• Self-test: stress-check<br>• Self-test: awareness of warning signs<br>• Reflection-questions: "Think about what stresses you in everyday life", "How does your family/friends recognize that you are stressed?" "Which of your stress reactions do you want to get a grip on?" |
| **2. Counterproductive thoughts and actions**<br>The students learn about maladaptive coping behaviors, which might increase stress, the risk of chronic stress and stress-related diseases in later life (e.g., postponing problems, resignation, rumination, perfectionism, smoking, substance abuse). | Negative thoughts during exhausting exercises (e.g., 30-minute run, circuit training) or unequal game situations (e.g., two against one) are discussed following the exercise. Reflection: What are counterproductive thoughts and actions in students' everyday life? | • Read background on different coping strategies and counterproductive thoughts and actions.<br>• Make a note of your personal weaknesses and strengths referring to school/work/peers<br>• Make a list of the positive things in your life. |
| **3. Eliminate sources of stress**<br>The students learn how to address problems efficiently. Many problems in today's world can be solved by problem-focused coping strategies. | Teamwork: e.g., cross the gym without touching the ground. Reflection: What sources of stress appear in the gym? Which team was faster and why? What was good about a certain strategy? | • Read background on problem solving cycle.<br>• Fictional story of a typical problem of vocational students at work: How would you try to solve the problem according to the 5 points of the problem solving cycle? Note your thoughts in the appropriate spaces.<br>• Self-test: Desirability of control<br>• What burdens you / makes you happy with work/school/family/friends? Are you able to change these incidences? |
| **4. Develop mental strength**<br>The students learn how to handle negative thoughts (e.g., rumination, resignation). For this purpose exercises should be selected which are physically demanding for the learners. Emerging negative thoughts are to be discussed together. | Negative thoughts during exhausting exercises (e.g., 30-minute run, circuit training) or unequal game situations (e.g., two against one) are provoked. Reflection: Negative thoughts are identified and rephrased positively with the group. Exercise on how to perform mindfulness training. | • Read background on the vicious circle of negative thoughts<br>• Reformulate sentences about a typical work/school annoyance into a positive statement.<br>• Task with protocol: Praise yourself for a week several times a day. Note your experiences. How did you feel? Did it work?<br>• Examples and practice task for positive self-talk, e.g., during exams.<br>• Read tips on how to assert yourself in interactions with your boss or unfair colleagues.<br>• Self-test: How self-confident are you?<br>• Tips: How to appear self-confident!<br>• Task: Mindfulness training |
| **5. Relax – Take it easy**<br>The students should learn that time-outs are not lost-time. Every student should find his/her personal relaxation strategy. Therefore, the students get to try out various relaxation techniques. This module aims at fostering emotion-focused coping strategies. | Yoga, progressive muscle relaxation (PMR), breathing exercised, and music are introduced. Reflection: Which activities were beneficial? Which techniques are used at home/stressful times? | • Read background on emotions<br>• Task with protocol: Self-observation of your emotional reactions in everyday life for one week.<br>• Self-test: How well do you relax in stressful situations?<br>• Introduction to PMR, breathing exercise, yoga, effects of different types of music with instructions.<br>• Task with protocol: Try one or more relaxation techniques. Note quantity, time and effects on you.<br>• Self-test: sleep quality<br>• Tips on sleep hygiene |
| **6. Manage stress together**<br>Students learn that social support is an important resource in times of stress, as it can both be useful in both problem-focused and emotion-focused coping with stress. | The given exercise tasks are easier to complete with more than one student. However, teachers should not refer to this option at the beginning. Do the students recognize this option? Reflection: Which group is better? Why was someone chosen for help? | • Read background on social support<br>• Task: Draw your social network using the following graphic. "Who is close to you?", "Who would you most likely ask for help?"<br>• Self-test: What`s your type of social competency?<br>• Task with protocol: In the following week, ask someone for help every day. Note your experiences. Is it hard for you to approach others? |
| **7. Successful time management**<br>The students need to agree on a common goal (e.g., time of 30-minute run). With the help of the student workbook they need to define main aims, sub-aims, a time plan, possible barriers and counter strategies. | Pre-/posttests: a timed run (30 minutes), circuit training, motor skills in ball games. Reflection: How are goals achieved? Were goals achieved after a specific training period? Possible barriers and counter strategies. | • Read background on time pressure<br>• Weekly plan: How do you spend your time?<br>• Analyze your time consuming activities.<br>• Read background on goal setting and the role of physical activity as a stress buffer.<br>• Task: What is your sporting goal? What are your subgoals? What could be possible barriers to prevent you from doing sport? What could be a strategy to overcome this barrier? Fill out the training log. Follow-up questions: Did you achieve your goals? Was your goal formulated concretely enough? If not, change it now. Which barriers did you face? Did you expect them? Would you evaluate your barrier-management as successful? Any proposed amendments? |
| **8. Summary and closing event**<br>During a special event (e.g., climbing) certain situations are highlighted by the teacher and connected to the coping program (e.g., stress is individual, relaxing techniques, positive thoughts). | Activities depend on facility of gym/school area (e.g., climbing, mountain biking, river rafting). | |

**Measures**

*Socio-demographic background*

Information about students' social and demographic background was collected in the first section of the questionnaire. Students reported their gender, age and the financial situation of their family (as compared to peers) on a 5-point scale from 1 (*much worse*) to 5 (*much better*).

*Assessment of intervention fidelity*

To obtain information regarding the degree of program implementation with each class, a non-participating, standardized classroom observation was conducted in every lesson throughout the implementation. Following Dane and Schneider [50], the focus was on the quantity of program delivery, quality of program implementation, and the perceived responsiveness of the students. Additionally, the students of the IG were asked at the follow-up measurement (post hoc evaluation) whether (a) they read the workbook, (b) they think they have learned something from the stress management program, and (c) their teacher has reminded them to read the workbook and do the homework. Answers were given on a 5-point rating scale ranging from 1 (*not at all*) to 5 (*very much*).

*Assessment of main outcomes*

*Coping skills*. Coping skills were assessed with the Coping Questionnaire for Children and Adolescents [34,51]. The SVF-KJ consists of 36 items, which referred to the stem question: "How do you usually deal with stress? Imagine the following situation: If I feel stressed and if I am really worried about something, then …" The answers represent three coping styles; two coping styles (emotion- and problem-focused coping) are considered adaptive (positive coping). Emotion-focused coping describes youngsters' ability to mentally minimize problems (e.g., "I say to myself: That's not so tragic.") and to distract one-self from stressors (e.g., "I read something fun."). Problem-focused coping is represented by situation control (e.g., "I try to figure out what the problem is."), positive self-instructions (e.g., "I say to myself: I can make it."), and social support (e.g., "I ask for somebody's advice."). The third coping style (labeled negative coping) integrates maladaptive coping strategies such as passive avoidance (e.g., "I prefer to stay in bed."), rumination (e.g., "The situation rushes into my mind over and over again."), resignation (e.g., "I want to give up."), and aggression (e.g., "I get bad-tempered."). Answers are given on a 5-point Likert scale from 0 (not at all) to 4 (every time). Items were summed up, with higher scores representing a stronger tendency to use a particular coping style. In the present sample, the Cronbach's alphas for the three coping styles were $\alpha = .75$ for emotion-focused coping, $\alpha = .86$ for problem-focused coping, and $\alpha = .86$ for negative coping.

*Perceived stress*. Perceived stress was assessed with the Adolescents Stress Questionnaire (ASQ, 48). The ASQ measures the perceived stressfulness of events that adolescents commonly experience in their daily lives. The validity and reliability of the ASQ has been demonstrated in previous studies [6,52,53]. Originally, the ASQ consists of 58 items representing 10 subscales. For reasons of time, a shortened version with 30 items was used in the present study including those three items per subscale with the highest reported factor loadings [52]. Gerber et al. [23] have shown with CFA that the factorial validity of this shortened version is acceptable ($\alpha$=.90). As a stem question, students were asked how stressful they perceived a number of events in the past year to be (e.g., arguments at home, having to study things you do not understand, pressure to fit in with peers, employers expecting too much of you). Each item was rated on a 5-point Likert scale ranging from 1 (*not at all stressful* or *is irrelevant to me*) to 5 (*very stressful*). A sum score was built to obtain a total index, with higher scores reflecting higher stress levels. The Cronbach's alpha in the present sample was high ($\alpha$ = .90).

*Quality of sleep.* Quality of sleep was assessed with four items of the Insomnia Severity Index (ISI, 50) asking students about their difficulty falling asleep, difficulties staying asleep, and early morning wakening. A fourth item queried current sleep satisfaction. The items refer in part to the DSM-IV-TR criteria for insomnia [55]. The validity and reliability of this instrument has been established previously [56]. Answers were given on a 5-point rating scale ranging from 0 (*not at all*) to 4 (*very much*). Higher scores reflect poorer quality of sleep. The Cronbach's alpha in the present sample was $\alpha$ = .92.

**Statistical analysis**

Pearson's correlations were used to examine how age and family financial situation are associated with coping, stress, and quality of sleep. Chi square tests were calculated to determine gender differences in socio-demographic and main outcome variables. Results with an alpha level of below .05 were reported as significant. Between-group differences at baseline were tested with univariate analyses of variance (ANOVAs). Additionally, due to nested data, we calculated intraclass correlations (ICC) between classes in main outcome variables at baseline. Nested datasets require multilevel modeling, if there is variation in response variable scores across level-2 units (e.g., classes) (ICC > .05) [57,58]. The ICCs in the present data set (all ICC < .05) indicate that class affiliation has no relevant effect on main outcome variables at baseline.

To evaluate possible interaction effects of the coping training on coping skills we chose a two by two repeated measures ANOVA design with time (pre vs. post) and group (IG vs. CG). Likewise, possible time (pre vs. post) by group (IG vs. CG) interaction effects on stress perception and quality of sleep was tested with repeated measures ANOVAs. Additionally, in case of significant baseline differences in main outcome variables, between-group differences at follow-up were testes with univariate ANCOVAs. Effect sizes for

AN(C)OVAs (partial eta-squared [$\eta^2$]) were regarded as small if .01 > $\eta^2$ < .059, medium if .06 > $\eta^2$ < .139, and large if $\eta^2 \geq .14$ [59].

## RESULTS

### Program implementation

All modules were fully implemented. Furthermore, the implementation rate was judged high across all four intervention classes by the non-participating classroom observer. Seventy-five percent of the students reported they had read the workbook. Thirty percent of the girls and 22 % of the boys indicated they had read all parts of the workbook (and completed all tests and tasks), whereas 67 % of the girls and 43 % of the boys had read most parts of it. The students' perceived learning effect was associated with the degree to which they have completed the required readings, self-tests, and reflection tasks, $r = .40$, $p < .01$, and whether the teacher controlled for students` homework completion, $r = .39$, $p < .01$. The overall response to these questions was 100%. In summary, these findings show that the compliance of the teachers (program implementation) and the students (completion of homework) was relatively high.

### Differences between IG und CG students

*Baseline differences in the outcome variables*

Table 7.2 provides the descriptive and inferential statistics of all outcome variables, separately for both groups. Univariate ANOVAs show the two groups differed significantly in *emotion-focused coping* skills, with higher skills among students of the IG. No differences existed for the other study variables ($p > .05$).

*Differences across time between IG and CG (baseline to post-intervention)*

Table 7.2 provides the findings of the repeated measures ANOVAs. Significant main effects for time were observed for increased *emotion-focused coping* and *maladaptive coping*, and decreased *problem-focused coping*. No significant main effect for time was observed for *adaptive coping*, *perceived stress,* and *quality of sleep.* However, perceived stress remained relatively stable over time in both groups. Importantly, a significant time by group interaction effect was observed for *emotion-focused coping*, with greater increases in skills in IG. This effect was still observed, after controlling for baseline differences, $F(1,121) = 8.02$, $p < .01$, $\eta^2 = .063$. Furthermore, there was a trend showing that students of IG increased their adaptive coping skills, while these were decreasing among students of CG. No statistically significant interaction effects were found for the other outcome variables ($p > .05$).

**Table 7.2**
Descriptive and inferential statistics, separately for group (IG $n$ = 63 vs. CG $n$ = 59) and time (pre- vs. post-test intervention); $N$ = 122.

| | IG | | CG | | Statistics | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-test | Post-test | Pre-test | Post-test | | | | | Group x Time | |
| | $n$=63 | $n$=63 | $n$=59 | $n$=59 | Group | | Time | | interaction | |
| Variables | $M$ ($SD$) | $M$ ($SD$) | $M$ ($SD$) | $M$ ($SD$) | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ |
| Emotion-focused coping | 7.14 (2.47) | 7.97 (2.62) | 6.55 (2.56) | 6.64 (2.29) | 5.399* | .043 | 6.639* | .052 | 4.236* | .034 |
| Problem-focused coping | 9.83 (2.81) | 9.67 (3.04) | 9.57 (2.02) | 9.05 (2.24) | 1.027 | .008 | 4.067* | .033 | 1.084 | .009 |
| Adaptive coping | 8.75 (2.23) | 8.99 (2.53) | 8.36 (1.66) | 8.09 (1.80) | 3.356+ | .027 | 0.018 | .000 | 3.487+ | .028 |
| Maladaptive coping | 6.78 (2.63) | 7.11 (2.88) | 6.67 (2.59) | 7.20 (2.57) | 0.000 | .000 | 6.866* | .054 | 0.344 | .003 |
| Perceived stress | 5.99 (1.45) | 6.07 (1.81) | 5.85 (1.57) | 5.92 (1.53) | 0.318 | .003 | 0.358 | .0003 | 0.001 | .000 |
| Quality of sleep | 8.57 (3.18) | 8.40 (3.16) | 8.59 (2.99) | 9.02 (3.57) | 0.358 | .003 | 0.282 | .002 | 1.629 | .013 |

*Notes.* IG = intervention group; CG = control group, M = mean; SD = standard deviation. Degrees of freedom: Always 1,121. +$p$ ≤.07. *$p$<.05. Coping: higher scores reflect higher values on all subscales. Stress: higher scores reflect more perceived stress. Quality of sleep: higher scores reflect higher sleep complaints.

In summary, our first set of analyses partially supported the assumption that EPHECT has a positive impact on students' coping skills. However, a retrospective evaluation of the students revealed that one teacher checked homework by collecting EPHECT workbooks and validating completeness at the beginning of each class, and returning them at the end. This performance is of importance, in that the retrospective evaluation of the students also indicated that teacher's homework control was significantly associated with student's reflection and compliance. Therefore, we decided to carry out additional analyses in which we compared classes of the intervention group with homework control (IG II high student compliance $n$ = 37, 35% females) and classes without homework control (IG I $n$ = 26, 34% females) with the CG, respectively. While 83% of the students in IG II indicated having fully read the booklet (54% completed homework), this was the case for 65% of IG I, with only 10% completing homework tasks.

### Effects in intervention groups with low versus high compliance compared to controls

Table 7.2 provides the descriptive and inferential statistics of all outcome variables, separately for both groups (IG I vs. CG; IG II vs. CG). No differences were observed for age, gender, BMI, and family financial situation. Since we hypothesize greater improvements among highly compliant students, we chose two separate 2 X 2 repeated measures ANOVAs with time (pre vs. post) and group (IG I vs. CG; IG II vs. CG). A 2 X 3 design (IG I vs. IG II vs. CG) would be less adequate in this case, because the interaction effect is statistically underestimated. Since no significant time by group effects were found for students of the IG I, only results of IG II are reported in the following sections.

*Baseline differences for IG II in the outcome variables*

Univariate ANOVAs showed that students of IG II again had higher *emotion-coping* and *adaptive coping* skills than controls. No differences existed for the remaining study variables ($p > .05$).

*Differences across time between IG II and CG (baseline to post-intervention)*

Significant main effects for time were observed for *emotion-focused coping* (increasing) and *maladaptive coping* skills (decreasing). Again, perceived stress remained relatively stable over time in both groups. Notably, three significant time by group interaction effects were observed for *emotion-focused coping, problem-focused coping* and *adaptive coping* skills, with improved coping skills from pre- to post-intervention in the IG II compared to CG. The effects were still observed after controlling for baseline differences in *emotion-focused coping*, $F(1,95) = 9.71$, $p < .01$, $\eta^2 = .095$ and *adaptive coping* skills, $F(1,95) = 11.79$, $p < .001$, $\eta^2 = .112$. No statistically significant interaction effects were found for the other outcome variables (see Figure 5.1).

**Table 7.3**
Overview of inferential statistics, separately for group (IG I n = 26 vs. CG n = 59) and (IG II n = 37 vs. CG n = 59) and time (pre- vs. post-test intervention).

| | IG I vs. CG | | | | | | IG II vs. CG | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Group | | Time | | Group x Time interaction | | Group | | Time | | Group x Time interaction | |
| Variables | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ |
| Emotion-focused coping | 1.541 | .018 | 2.261 | .027 | 1.251 | .015 | 6.770* | .067 | 6.889* | .068 | 4.690* | .048 |
| Problem-focused coping | 0.028 | .000 | 11.261** | .119 | 0.671 | .008 | 2.120 | .022 | 0.288 | .003 | 5.012* | .051 |
| Adaptive coping | 0.552 | .007 | 2.243 | .026 | 0.002 | .000 | 5.579* | .056 | 1.170 | .012 | 8.947** | .087 |
| Maladaptive coping | 1.095 | .013 | 0.622 | .007 | 2.657 | .031 | 0.715 | .008 | 10.468** | .100 | 0.204 | .002 |
| Perceived stress | 0.416 | .005 | 0.547 | .007 | 0.091 | .001 | 1.714 | .018 | 0.102 | .001 | 0.038 | .000 |
| Quality of sleep | 0.798 | .010 | 0.267 | .003 | 3.770+ | .043 | 0.027 | .000 | 1.242 | .013 | 0.131 | .001 |

*Notes.* IG I = intervention group; IG II = intervention group + homework control; CG = control group. *M* = mean; *SD* = standard deviation. Degrees of freedom in IG I vs. CG always 1,84; in IG II vs. CG always 1,95 $^+p \leq .07$. $^*p < .05$. $^{**}p < .01$. Coping: higher scores reflect higher values on all subscales. Stress: higher scores reflect more perceived stress. Quality of sleep: higher scores reflect higher more sleep complaints.

In summary, the second set of analyses indicated that the most beneficial outcomes were achieved among students of the intervention group in which the teacher regularly controlled the students' homework (IG II). This increased student reflection and led to higher student compliance. At follow-up, these students reported significantly higher emotion- and problem-focused coping and adaptive coping skills than controls. No statistically significant interaction effects were found between students of IG I (intervention with no homework control) and controls.

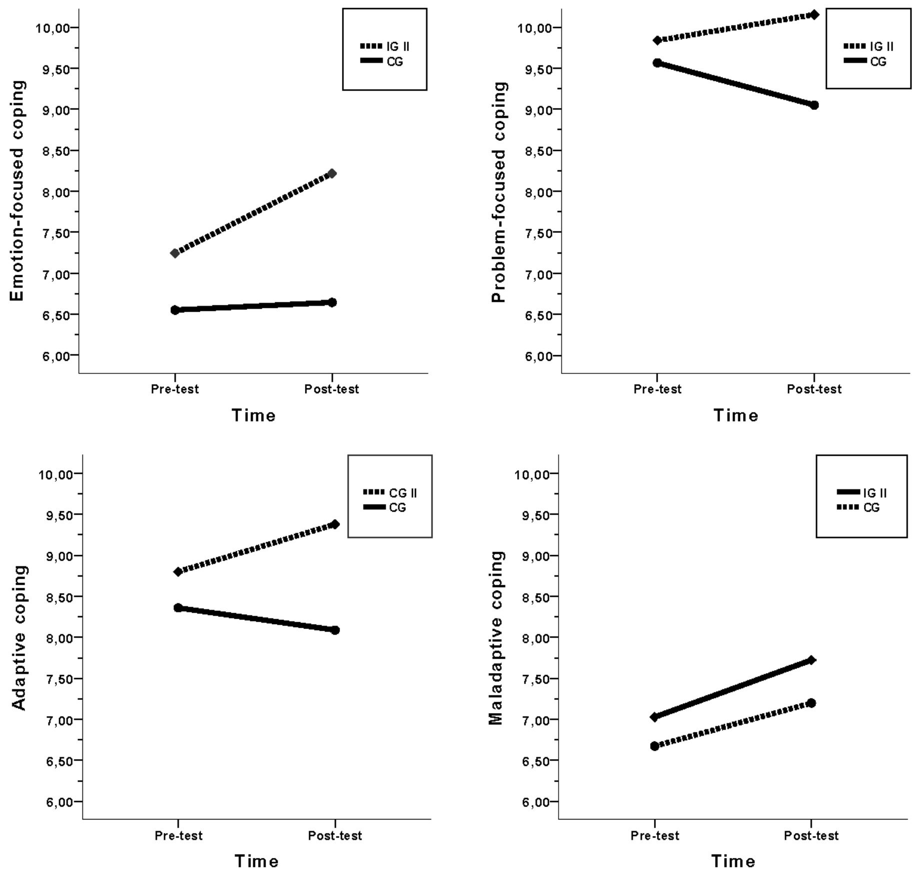


**Figure 7.1. Study 2**
Perceived adaptive coping skills (including emotion- and problem-focused coping) improved post intervention in IG II compared to CG (for inferential statistics see Table 7.4). T1 = pre intervention; t2 = post intervention; IG II = intervention group + homework control; CG = control group. For further descriptive statistical information, see supplemental online materials.

## DISCUSSION

The key findings of the present study are that a complete and accurate implementation of EPHECT can make a positive contribution to the development of adaptive coping skills among adolescents attending vocational schools. Thus, teaching stress-related knowledge in combination with practical experiences proved useful if the teachers ensured the students reflected on their experiences as part of their homework. Three hypotheses were formulated and each of these is now considered in turn.

## Effects on coping

First it was assumed that coping training would promote more adaptive and less maladaptive coping. A statistically significant effect showed that students of all intervention classes rated their emotion-focused coping skills higher post intervention compared to students of CG. As students of IG scored higher on emotion-focused coping at baseline, one could assume that this influenced higher outcome values at follow-up. However, after controlling for baseline-differences, this effect still appeared significant. Furthermore, a significant trend showed improved adaptive coping skills among intervention students. Students from classes in which teachers have performed regular homework checks (IG II) also rated their problem-focused coping skills significantly higher and used more adaptive coping strategies than students of the other intervention group (IG I) and controls. Again, these effects remained significant after controlling for higher baseline differences in IG II. Moreover, the observed time by group interaction effects occurred equally among males and females. This is important given that prior research has shown that school-based mental-health programs were more attractive to females than males [36,45,60,61]. However, the observed differences between IG and IG II indicate the program is particularly successful if teachers control whether students' have reflected on their experiences as a part of their homework. As a consequence, we recommend that homework during leisure time, as part of the stress management, should be reduced to a minimum. This critical issue for school-based mental-health programs has previously been referred to by Beyer [45]. If possible, readings and homework should be implemented within other classes (e.g. classes which include health education). Reflections, initiated by the PE teacher in connection with the student workbooks, are a core element of the coping training. We assume students are not used to being exposed to stressful tasks during PE lessons. Therefore, these experiences must be reflected on, so a transfer may take place from the gym into everyday and professional life. This is in accordance with the framework of experiential learning [39]. A concrete experience is followed by a reflection phase (supported by the PE teacher), in which the student can identify positive or negative thoughts, feelings, and actions and revise or continue with current coping strategies. Via a practice log in the workbook, students can plan and document their attempts.

## Effects on stress and sleep

Despite these promising findings, hypotheses 2 and 3 were not confirmed. There were no significant effects observed for perceived stress and quality of sleep. Both outcomes remained relatively stable over time. Although speculative, we assume EPHECT led to a gain in knowledge and awareness [36,45]. Thus, while adaptive coping skills improved, students from the intervention group might have become more sensitive to maladaptive coping skills, stress and sleep disturbances. Moreover, it was expected the strongest effects would occur for coping as the most proximal target variable of the EPHECT intervention. Thus, stress and quality of sleep were more distant outcomes, which depend on factors that are difficult to address directly through a school prevention program (e.g. work environment, family climate, relationships with peers) [36,47,62]. It should be noted that effects of primary prevention programs with participants of a normal psychological range are less distinctive than in secondary preventive programs. This may have reduced the possibility of detecting significant interaction effects because most vocational students reported low or medium stress levels [31], and the majority of them also an acceptable quality of sleep. Yet, primary prevention programs to foster adolescent's adaptive coping skills are a great need at this early stage, in order to reduce or avoid possible future experience of chronic stress [10].

Given this background, Fridrici and Lohaus [36] argued that reducing stress and improving health (e.g., quality of sleep) should not be the primary focus of primary prevention programs. Rather, preventive interventions should seek to foster protective factors, which reduce the likelihood of negative outcomes or increase participants' resilience resources. Thus, having an appropriate coping repertoire may help to reduce the long-term risk for stress-related diseases [11]. In this respect, the findings were encouraging given that the development of coping skills depends on multiple factors, and PE makes up only a little part of vocational students' (professional) life.

**Strengths and limitations**

A major strength of the study is that the intervention uses a new experience-based approach in conveying psychological theory to adolescents attending vocational schools. It allows students to experience their stress-responses directly and to experiment with different coping strategies. Another strength is that the program is implemented by the PE teachers on their own. As mentioned previously, most school based coping training programs are taught by psychologists or trained study personnel [32,37,45]. The advantage of implementing the program through PE teachers is that the course of the lesson is barely affected (the contents of the program are designed for seven different sports and can be added to the regular motor skill training). This often plays an important role for schools and teachers in deciding on longitudinal health interventions implemented within their curriculum. Furthermore, sooner or later among most intervention programs, the question of funding in the long run arises. Providing intervention materials, an online platform and workshops enables PE teacher to implement the coping training on their own.

Despite these positive findings, several considerations warn against their over-generalization. First, the study uses a pre-post design. However, to find out if changes persist over time, longer-term follow-ups are important. Second, data are based on a non-clinical sample. Therefore, a reduction in perceived stress levels and maladaptive coping skills is less distinctive from before to after the intervention. As the program was designed as a primary prevention for first year vocational students, the main aim was to improve coping skills, in order to prevent worsening stress and sleep scores later on. Third, dropouts differed on some variables at baseline (age and perceived stress). This might be because older students feel more stressed than VET beginners. Therefore, we conducted an intention-to-treat analysis (LOCF). Fourth, one teacher has done homework control, which influenced student's reflection and compliance. As a result, we conducted a second set of analyses. Fifth, one could argue that the EPHECT intervention could just as well be implemented in theoretical classes. Nevertheless, this is not the purpose of this program, which was specifically developed for the implementation in PE. Thus, the theoretical information in each module is connected with a specific experience made previously during a PE class. Therefore, presenting the theory without the procedural practical experience would correspond to a truncation, which is incompatible with the underlying idea of experiential learning. Therefore, we decided not to include a second control group. Nevertheless, comparing EPHECT with more traditional classroom coping programs seems worthwhile in future research. Moreover, research is needed to examine how teaching coping skills aligns with other (more proximal) goals of PE (e.g. motor learning, activity time). Sixth, the sample was based on adolescents who attended a vocational school in the German-speaking part of Switzerland, and they are therefore not representative of the entire population of vocational students in Switzerland (e.g. students in the French-speaking part) or in other German-speaking countries with a similar VET system. More research is needed to find out whether similar findings apply to the latter and other dual VET systems across the world. Last, the coping program was closely monitored by a passive observer, and the possible influence of this observer has not been controlled for here.

## CONCLUSION

Findings from the current trial provide evidence that this unique PE based coping training can be an effective method of promoting vocational students' adaptive coping skills. The successful acquisition of new knowledge and insights, and the belief in one's own capacity to cope with stress, may constitute a springboard which, in the long run, may help vocational students to reduce their risk for stress-related disorders in later life. Therefore, routine implementation of such a program by PE teachers can be particularly helpful for vocational students who start out on their professional life and who might be faced with new challenges and exposed to unknown stressors. However, future studies should also address second and higher-grade levels as well as other professional training groups, to increase the generalizability of the present results.

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# CHAPTER 8

## Stress management in physical education class: An experiential approach to improve coping skills and reduce stress perceptions in adolescents (EPHECT II).

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# STRESS MANAGEMENT IN PHYSICAL EDUCATION CLASS: AN EXPERIENTIAL APPROACH TO IMPROVE COPING SKILLS AND TO REDUCE STRESS PERCEPTIONS IN ADOLESCENTS (EPHECT II)

## ABSTRACT

In most PE syllabuses, promoting life skills constitutes an important educational objective. The aim of this study was to implement a coping training program (EPHECT) within regular PE and to evaluate its effects on coping and stress among vocational students. Eight classes from a vocational school were selected for study; four were allocated to the intervention group (IG) and four to the control group (CG). The study examined intervention effects between pre- and post-intervention, and post-intervention and 6-months follow-up. Compared to the CG, the IG showed improved coping skills from pre- to post-intervention. From post-intervention to follow-up, stress decreased for the IG. A path analysis suggests an indirect effect on stress perception at follow-up via improved adaptive coping skills. The findings support EPHECT as a positive contribution to the development of adaptive coping skills. The project further shows how physical educators can translate psychological theory into practice.

**Keywords:** Adaptive coping, health promotion, psychological training, skill practice, students, vocational school

## INTRODUCTION

Although conceptual diversity in PE across different cultural and educational systems is a common phenomenon [1], health has become an increasingly important topic [2]. Bearing in mind that an expanding body of literature suggests that adolescence is a vulnerable period in the development of psychiatric disorders [3], the need to promote mental health in society is receiving increasing attention at national and international levels [4]. Growing awareness of the long-term negative consequences of stress has resulted in governments increasingly looking to schools as a setting for promoting resilience (ability to recover from or adjust easily to misfortune or change) in young people. At the same time, it appears that PE may have the potential to provide educative experiences through physical activity [5]. Therefore, the promotion of mental health within PE is almost universally used to legitimize its place in the school curriculum [1]. For instance, in Switzerland, the new PE curriculum for vocational students explicitly addresses stress management as an issue, because stress related diseases in working life have become a major concern among young professionals in the country [6].

However, few strategies have so far been advanced for improving mental health in PE [4]. Furthermore, physical educators are insufficiently instructed in how to teach appropriate behavior management skills [7], such as adaptive coping abilities. These include the abilities to solve personal problems, and to master, minimize or tolerate stress and conflicts [8,9]. Further empirical research is required to establish specific implementation proposals within PE curricula and through which the potential of experience-driven education to foster adolescent resilience might be realized.

**Vocational students – a risk population?**

Although most adolescents successfully manage the transition from childhood to adulthood, the speed and extent of changes in physiological, socio-cultural and psychological factors can exceed their coping abilities [10,11]. The effect of daily stressors can be particularly harmful to the wellbeing of young people [12]. Moreover, high stress levels promote maladaptive coping strategies such as smoking, alcohol consumption, and the use of illegal drugs [13,14]. Once acquired during adolescence, maladaptive coping behaviors can be retained for a lifetime and cause serious health problems [15]. For vocational students, additional challenges arise from the transition to a vocational school and the need to balance academic and job-related requirements [6]. Vocational students are therefore especially at risk for stress-related health complaints including depression, insomnia, and substance abuse [6].

Despite these insights, there is still little research on the relationship between stress and coping among vocational students. This is surprising given that in some countries such as Switzerland, Austria, Germany and Liechtenstein, vocational education and training (VET) is an important part of the education systems. For instance, in Switzerland the majority of all secondary school diplomas (74%) are granted to students with VET [16]. Swiss VET combines apprenticeships in a company (3-4 days) and vocational training in a school (1-2 days). The VET systems in the other German speaking countries are very similar to the Swiss system and a vocational qualification from one country is generally also recognized in the other states within this area.

**Promoting coping skills in PE class**

Growing evidence suggests that internal resources, such as the ability calmly to process a situation or maintain a positive outlook, are important mediators in the relationship between perceived stress and healthy development [15,17]. Therefore, building up a broad and balanced repertoire of adaptive coping skills is key to fostering adolescents' resilience[18].

Although some in-school coping training programs exist for this age group, most of them are based on theoretical education in a classroom setting and taught by psychologists or trained study personnel e.g. [19,20]. In contrast, PE has the potential to integrate both theoretical and practical experiences of stress by introducing challenging tasks which replicate stressful situations (such as falling backwards from a box onto a mat or two-against-one game situations). This approach incorporates the idea of experiential learning in which the process of learning new coping skills occurs through active reflections on concrete situations in the gym [21]. If students are confronted with stressful or apparently insoluble tasks in PE they need to apply appropriate coping skills. In a short reflection following the tasks, experiences of adaptive and maladaptive coping strategies (e.g., positive vs. negative self-talk) can be discussed to reinforce the practical applications. Furthermore, reflecting on students' individual stress responses can be a useful way to increase student mental health awareness.

The idea that PE not only promotes motor learning but also contributes to the development of life skills has a long history [1]. Pühse and Gerber [1] conclude, in their cross-national comparison of PE-curricula, that health education is a core element in most countries. While relaxation exercises, such as breathing exercises, progressive muscle relaxation and mindfulness techniques are increasingly performed during PE class and health interventions [19,22], only a few in-school health programs have continuously implemented their intervention contents in PE classes. For example, the American COPE program (Creating Opportunities for Personal Empowerment) includes 15-20 minutes of physical activity in every session to build belief in students that they can engage in physical activity on a regular basis [23]. Although the promotion of life skills is increasing within current PE curricula, this topic is rarely addressed in PE teacher education. Specifically, PE teachers lack professional knowledge regarding how to translate psychological theory into pedagogical practice.

**Purposes and hypotheses**

Given this background, the purposes of the present study were threefold. First, based on a series of field-tested coping training programs, we developed coping training for adolescent vocational students. Additionally, we introduced psychological theory through movement-based tasks that allowed students to experience various processes involved in the regulation of stress. The main aim of the EPHECT intervention (Effects of a Physical Education based Coping Training) was to foster vocational students` resilience through the development of an individual and adequate coping repertoire.

Second, we intended to evaluate the program's effectiveness related to changes in (a) perceived coping skills and (b) stress perception. Thus, we focused on a direct comparison between an intervention group and a control group. We hypothesized that the coping training would result in moderate improvements in self-reported coping skills as the most proximal outcome assessed following the intervention [19,24,25], whereas no changes were expected in the control group (Hypothesis 1). We also anticipated that the intervention would in the medium term (follow-up assessment)lead to reduced stress perceptions in the intervention group as compared to the control group [24,26] (Hypothesis 2).

Third, we drew on the cognitive-transactional stress model of Lazarus and Folkman [9], which defines stress as a transaction (interaction) between the person and the environment. Thus, stress occurs if there is an imbalance between internal or external demands and perceived resources available to cope with stress. We therefore sought to examine whether there is empirical support for a model positing that improvements in coping skills (pre- to post-intervention) contribute to reduced stress perception among vocational students in the medium term (post-intervention to follow-up). As Lazarus and Folkman [9] state, personal resources can change over time due to coping effectiveness. Therefore, we assumed that reduced stress perception at follow-up (six months after the intervention has finished) would be predicted by improved adaptive (emotion- and problem-focused) coping skills (Hypothesis 3).

## METHOD

### Participants and procedure

A total of 131 students ($M_{age}$ = 16.22, *SD* = 1.12, 35.2 % females) from eight classes of a vocational school in central German-speaking Switzerland participated in this cluster randomized controlled trial. First, the school's principal was contacted concerning the possibility of conducting the study at this location. The school has a population of 1189 students distributed across 70 classes, all of them participating in at least one 90-minute PE lesson per week. PE lessons were taught by six PE teachers (5 males, 1 female). Five teachers were highly motivated to implement EPHECT (4 males, 1 female). Of these, we randomly selected two teachers for participation in this study (2 males, $M_{age}$ = 40.50, *SD* = 9.89). Two classes of each teacher (four classes in total) were randomly assigned to the EPHECT intervention (intervention group = IG; *n* = 67; $M_{age}$ = 15.96, *SD* = 1.04, 32.4 % females). The other four classes (control group = CG; *n* = 64; $M_{age}$ = 16.44, *SD* = 1.09, 31.7 % females) participated in conventional PE lessons and were not informed about the intervention. To minimize the likelihood that students in the coping program would talk about the specific contents of the program to students in the control condition, the randomization involved classes, which did not attend school on the same day.

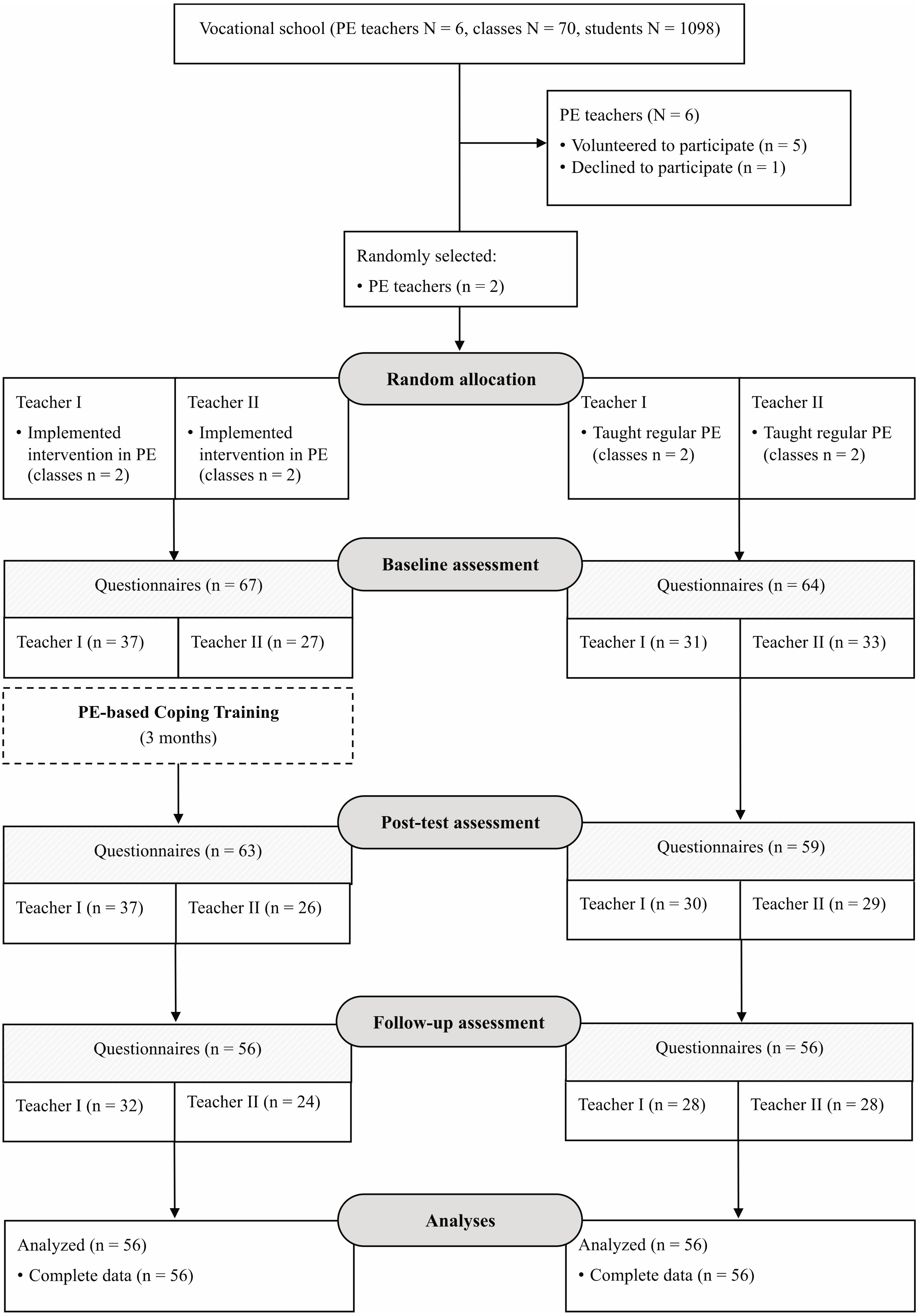


**Figure 8.1. Flow diagram for recruitment and analysis of participants.**

The study was conducted during a school year from mid-August 2012 to the end of June 2013. The intervention program was carried out every week (excluding vacation) between August and November 2012. To evaluate impact of the 3-month EPHECT intervention on coping and stress, all students completed three series of questionnaires related to socio-economic background, perceived stress and coping strategies. Baseline data were collected in August 2012, post-intervention data were collected in November 2012, and follow-up data in June 2013. Complete data for all three assessments were available from 112 students (IG n = 56; CG n = 56). In total, 14% of the students missed either the second or third assessment (due to authorized absence on the assessment day). Dropout analysis revealed no significant differences between students with complete and incomplete data. Moreover, an intention-to-treat analysis (with Last-Observation-Carried-Forward; LOCF) did not show a different trend for non-completers from baseline to follow-up. Among the final sample, significant baseline differences between IG and CG were found for age, $F(1,111) = 7.12$, $< .001$, $\eta^2 = .061$ [S], with a higher mean age among students in the CG (IG: $M = 15.96$, $SD = 1.04$; CG: $M = 16.44$, $SD = 1.15$). No differences were observed for gender, BMI, demographic characteristics or family financial situation.

All participants completed the questionnaires during class hours in the presence of a trained research assistant. The study was approved by the local ethics committee and was performed according to the ethical standards in the Declaration of Helsinki.

**Intervention materials, teacher training and degree of implementation**

The contents of the EPHECT intervention are derived from a series of field-tested coping training programs [19,25,27]. Components of these programs were adapted and tailored specifically for VET students facing the dual burden of academic and work-related requirements. Additionally, drawing on the experiential learning theory of Kolb [21], we adapted the contents of the coping training for their use in PE. The intention was to provide tasks for the individual student or the group, which allowed them to learn about the nature and regulation of stress (e.g., to address awareness of potentially stress-accelerating cognitions, problem solving skills, and relaxation techniques). After completion, the teacher briefly reflected with the students on how the task related to stress regulation (see Table 8.3 for more details, provided as supplementary online file).

EPHECT consists of eight modules, which are implemented in regular PE classes by the PE teacher. While module 1 addresses basic knowledge about the development of stress, the following six modules concentrate on aspects related to emotion- and problem-focused coping. Finally, module 8 serves to bolster consolidation, whereby students actually apply the learned contents (a detailed description of the modules is provided on www.ephect.unibas.ch.

To integrate the program into the regularly scheduled PE course, each module is linked with one or several motor learning tasks, which is then followed by a short reflection phase moderated by the PE -teacher. Overall, the weekly implementation of each module requires about 20 minutes. To limit the time necessary for imparting theoretical knowledge during PE lessons, each student received an EPHECT booklet for homework assignments. Reflection tasks in the booklet encouraged the students to transfer the experiences gained in PE to other domains of life. This can be illustrated by an example from Module 1 entitled, "Experience and understand stress". This module contains three key messages. First, stress is individual: the students should understand that the same situation could lead to different perceptions and reactions in different people. Second, one should be aware of stress: the student's sensitivity to his or her own stress reaction (e.g., fast heart beat, stomach ache) should be increased. Third, one should pay attention to warning signs: in order to prevent chronic stress, it is important that students listen to warning signs from the body (e.g., headache, fatigue, back pain) and know when it is time for a break or change. These contents are addressed in PE through challenging tasks for the individual student (e.g., one student had no fear of falling backwards from a height of 3 meters onto a mat, but felt extremely uncomfortable crawling through a tunnel of mats) and reflected on afterwards. During the reflection period, the teacher, knowing the task was stressful, asked the students to report their feelings. The teacher further probed, "Have you experience similar feelings in everyday life?" The student booklet delves deeper into this theme by asking, for example, "What are stressful events in your everyday life?", "How do your friends/family recognize that you are experiencing stress?", and "Which stress reaction would you most like to get under control?" Additionally, the third module aims to show students how to address problems efficiently, implementing a problem-solving task. During the PE class, students are challenged to cross the gym without touching the ground. The reflection tasks in their homework provide typical working-life problems, which also need to be resolved according to the same problem-solving cycle.

To keep the workloads for the teachers low and to facilitate standardization of the program, each teacher received an EPHECT teacher manual. This manual provided a detailed description of all modules, complemented by a teacher training which involved two half-day workshops. Additionally, to obtain information regarding the degree of program implementation with each class, a member of the investigative team passively observed every PE lesson throughout the implementation phase, using a standardized observation form. The degree of implementation was judged high across all four intervention classes and was thus deemed suitable for use in all groups..

## Measures

### *Socio-demographic background*

Information about students' social and demographic background was collected in the first section of the questionnaire. Students reported their gender, age and the financial situation of their family (as compared to peers) on a 5-point scale from 1 (much worse) to 5 (much better).

*Coping skills*

Coping skills were assessed with the Coping Questionnaire for Children and Adolescents (Stressverarbeitungs-Fragebogen für Kinder und Jugendliche, SVF-KJ) [28]. The SVF-KJ consists of 36 items, which referred to the stem question: "How do you usually deal with stress? Imagine the following situation: If I feel stressed and if I am really worried about something, then…". In accordance with cognitive-transactional stress theory [8,9], the SVF-KJ assesses three coping styles; two of these (emotion- and problem-focused coping) are considered adaptive. Emotion-focused coping describes youngsters' ability to reframe and to mentally minimize problems (e.g., "I say to myself: That's not so tragic.") and to distract oneself from stressors. Problem-focused coping is represented by situation control (e.g., "I try to figure out what the problem is."), positive self-instructions,, and social support. The third coping style (labeled maladaptive coping) integrates maladaptive coping strategies such as passive avoidance (e.g., "I prefer to stay in bed."). Potential answers are rated on a 5-point Likert scale from 0 (not at all) to 4 (every time). Scores across items were summed, with higher overall scores representing a stronger tendency to use a particular coping style. The factorial structure of the SVF-KJ has been validated by Hampel, Petermann and Dickow [28]. Assignment of items was confirmed via factor analysis by Hampel and Petermann [27]. Likewise, factor analysis of subscales replicated the three coping styles, which accounted for 66% of the total variance in coping with interpersonal stressors. Internal consistencies for the coping strategies used with interpersonal stressors ranged from .66 to .84 (mean Cronbach's alpha = .72, Fisher's z-transformed); Cronbach's alphas for the emotion-focused, problem-focused, and maladaptive coping were .70, .82, and .82, respectively [28]. In the present sample, the Cronbach's alphas for the three coping styles were $\alpha = .75$ for emotion-focused coping, $\alpha = .86$ for problem-focused coping, and $\alpha = .86$ for maladaptive coping.

*Perceived stress*

Perceived stress was assessed with the Adolescent Stress Questionnaire (ASQ) [29]. The ASQ measures the perceived stressfulness of events that adolescents commonly experience in their daily lives. The validity and reliability of the ASQ has been demonstrated previously [29,30]. The full ASQ consists of 58 items representing 10 subscales. For reasons of time, a shortened version with 30 items was used in the present study including those three items per subscale with the highest reported factor loadings [29]. Gerber et al. [31] have shown with confirmatory factor analysis that the factorial validity and internal consistency (Cronbach's alpha = .90) of this shortened version are acceptable. As a stem question, students were asked how stressful they perceived a number of events in the past year (e.g., arguments at home, having to study things they do not understand, pressure to fit in with peers, employers expecting too much of them). Each item was rated on a 5-point Likert scale ranging from 1 (not at all stressful or is irrelevant to me) to 5 (very stressful). Items were summed up to build a total index, with higher scores reflecting higher stress levels. The Cronbach's alpha in the present sample was high ($\alpha$ = .90).

**Statistical analyses**

Pearson's correlations revealed how age and family financial situation were associated with coping and stress. Chi-square tests were performed to determine gender differences in socio-demographic and main outcome variables. Results with an alpha level of below .05 were reported as significant. Between-group differences at baseline were tested with univariate analyses of covariance (ANCOVAs). Additionally, due to nested data, we calculated intraclass correlations (ICC) between classes in the main outcome variables at baseline. Nested datasets require multilevel modeling if there is variation in response variable scores across level-2 units (e.g., classes) ($ICC$ > .05) [32]. The ICCs in the present data set (all $ICC$ < .05) indicate that class affiliation has no relevant effect on the main outcome variables at baseline.

To evaluate possible interaction effects of the coping training on coping skills, we chose a two-by-two repeated measures ANCOVA design with time (pre vs. post) and group (IG vs. CG) as fixed factors, and with age as covariate because of significant baseline differences. Likewise, possible time (post vs. follow-up) by group (IG vs. CG) interaction effects on medium-term stress perception were tested with repeated measures ANCOVAs, with age as covariate. As we hypothesize a time-lagged intervention effect on stress perception, a three-by-two design would be less adequate in this case because the interaction effect is statistically underestimated. Therefore, two separate two-by-two analyses were performed. Effect sizes for ANCOVAs (partial eta-squared [$\eta^2$]) were regarded as small if .010 > $\eta^2$ < .059, medium if .060 > $\eta^2$ < .139, and large if $\eta^2 \geq$ .140 [33]. Descriptive statistics, ICCs and ANCOVAs were computed using SPSS 22.

Potential effects of improved coping skills at the post-intervention assessment on reduced stress perception at follow-up were analyzed with path analyses using AMOS 21.0 (IBM Corporation, NY, USA).

## RESULTS

### Coping skills

Table 8.1 provides the descriptive and Table 8.2 the inferential statistics for all outcome variables separately for both groups, with age as covariate. Univariate ANCOVAs revealed that the groups did not differ in baseline scores ($p > .05$). Repeated measures ANCOVAs show significant main effects for time for both adaptive coping, $F(1,111) = 7.08$, $p < .01$, $\eta^2 = .060$, and maladaptive coping, $F(1,111) = 7.92$, $p < .01$, $\eta^2 = .067$. A significant time by group interaction effect was observed for adaptive coping directly after the intervention (pre vs. post), with improved skills in the IG, $F(1,111) = 5.86$, $p < .05$, $\eta^2 = .050$. In contrast, no statistically significant interaction effects were found for maladaptive coping skills ($p > .05$) over the same time period. Both adaptive coping and maladaptive coping remained relatively stable for the next six months (post vs. follow-up), in both the IG and CG ($p > .05$).

**Table 8.1**
Overview of descriptive values, separately for group (IG $n = 56$ vs. CG $n = 56$), and time (baseline, post-test and follow-up); $N = 112$

| | IG | | | | | CG | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline | Post test | | Follow up | | Baseline | Post test | | Follow up | |
| | $n = 56$ | $n = 56$ | | $n = 56$ | | $n = 56$ | $n = 56$ | | $n = 56$ | |
| | | | 95% *CI of* | | 95% *CI of* | | | 95% *CI of* | | 95% *CI of* |
| Variables | *M (SD)* | *M (SD)* | *difference t2-t1* | *M (SD)* | *difference t3-t2* | *M (SD)* | *M (SD)* | *difference t2-t1* | *M (SD)* | *difference t3-t2* |
| Adaptive coping | 7.11 (2.48) | 8.06 (2.63) | [0.47, 1.43] | 7.62 (2.70) | [ 0.95, 0.06] | 6.81 (2.82) | 6.86 (2.63) | [ 0.57, 0.53] | 6.89 (2.28) | [ 0.63, 0.72] |
| Maladaptive coping | 6.85 (2.69) | 7.28 (2.90) | [0.01, 0.82] | 6.98 (2.66) | [-0.80, 0.40] | 6.69 (2.92) | 7.21 (2.62) | [0.04, 1.03] | 7.13 (2.66) | [-0.57, 0.44] |
| Perceived stress | 6.02 (1.33) | 6.19 (1.86) | [-0.20, 0.53] | 5.87 (1.75) | [-0.75, 0.12] | 5.82 (1.57) | 5.98 (1.57) | [-0.63, 0.72] | 6.10 (1.69) | [-0.29, 0.41] |

*Notes.* IG = intervention group; CG = control group. *M* = mean; *SD* = standard deviation. Coping: higher scores reflect higher values on all subscales. Stress: higher scores reflect more perceived stress.

### Stress perception

Table 8.1 provides the descriptive data and Table 8.2 the inferential statistics for all outcome variables separately for both groups, with age as covariate. A univariate ANCOVA revealed that the groups did not differ in baseline scores ($p > .05$). An ANCOVA with repeated measures revealed no significant main effect for time ($p > .05$). While stress perception remained relatively stable in both groups from baseline to the post-intervention assessment, a significant time by group interaction effect was observed at follow-up, $F(1,111) = 3{,}82$, $p < .05$, $\eta^2 = .035$, indicating decreased stress perceptions in the IG.

In summary, the first set of analyses partially supports the assumption that EPHECT has a positive impact on students' coping skills. Importantly, while the coping training did not lead to reduced stress perception directly after the intervention, as expected, students in the IG reported reduced stress at the 6-months follow-up. Whether reduced stress levels are a direct effect of the intervention program or mediated via improved adaptive coping skills post-intervention remains unclear. This assumption will be addressed in the path analyses presented in the following section.

**Table 8.2**

Overview of inferential statistics, separately for group (IG n = 56 vs. CG n = 56), and time (pre- vs. post-test; post-test vs. follow-up); N = 112

| | Pre- vs. post-test | | | | | | Post-test vs. follow-up | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Group | | Time | | Group x time interaction | | Group | | Time | | Group x time interaction | |
| Variables | *F* | $\eta^2$ | *F* | $\eta^2$ | *F* | $\eta^2$ | *F* | $\eta^2$ | *F* | $\eta^2$ | *F* | $\eta^2$ |
| Adaptive coping | 2.86 | .025 | 7.08** | .060 | 5.86* | .051 | 4.39* | .039 | 0.87 | .008 | 1.32 | .012 |
| Maladaptive coping | 0.05 | .000 | 7.92** | .067 | 0.07 | .001 | 0.01 | .000 | 0.61 | .006 | 0.14 | .001 |
| Perceived stress | 0.56 | .005 | 1.85 | .017 | 0.00 | .000 | 0.06 | .001 | 3.02 | .027 | 3.82* | .035 |

*Notes.* IG = intervention group; CG = control group. *M* = mean; *SD* = standard deviation. Degrees of freedom always = 1,111; **p* < .05. ***p* < .01. Covariate: age.

In summary, the first set of analyses partially supports the assumption that EPHECT has a positive impact on students' coping skills. Importantly, while the coping training did not lead to reduced stress perception directly after the intervention, as expected, students in the IG reported reduced stress at the 6-months follow-up. Whether reduced stress levels are a direct effect of the intervention program or mediated via improved adaptive coping skills post-intervention remains unclear. This assumption will be addressed in the path analyses presented in the following section.

### Impact of improved coping skills on medium-term stress perception

Figure 8.2 represents the hypothesized path model. After controlling for baseline ($\beta_{\text{Coping t1} \rightarrow \text{Coping t2}}$ = .70, *p* < .001), the coping training shows a direct effect on adaptive coping skills post-intervention ($\beta_{\text{Intervention} \rightarrow \text{Coping t2}}$ = .28, *p* < .001). Consistent with hypothesis 3, the coping training showed no direct effect on stress either at post-intervention or at follow-up. Thus, both paths were set to zero. However, after controlling for post-intervention stress perceptions ($\beta_{\text{Stress t2} \rightarrow \text{Stress t3}}$ = .45, *p* < .001), the path analyses revealed a time-lagged intervention effect on perceived stress at follow-up via improved adaptive coping skills post-intervention ($\beta_{\text{Coping t2} \rightarrow \text{Stress t3}}$ = -.20, *p* < .05). In total, the path analysis explains 24 % of the variance in perceived stress at follow-up.

The model fit statistics suggest a good fit of this mediation model to the sample data ($\chi^2$[10, N = 112] = 8.61, *p* = .569; Goodness of Fit Index [GFI] = .97; Adjusted Goodness of Fit Index [AGFI] = .93; Tucker-Lewis Index [TLI] = 1.00; Comparative Fit Index [CFI] = 1.00; Root Mean Square Error of Approximation [RMSEA] = .00).

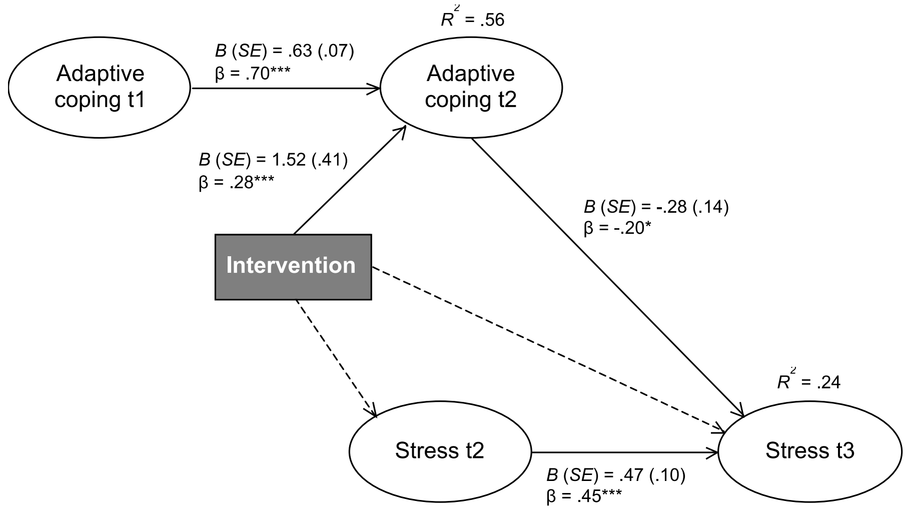


**Figure 8.2. Path analysis with beta weights and levels of explained variance ($R^2$).**
*Notes: B* = unstandardized coefficient; *SD* = standard error; β = standardized coefficient; t1 = baseline, t2 = post-test, t3 = follow-up; dashed arrows denote non-significant paths; intervention is 0,1 dummy-coded: IG = 1, CG = 0; *p* < .05. ***p* < .01. ****p* < .001; overall fit indices were good: $\chi^2$(6, *N* = 112) = 5.05, *p* = .538; GFI = .97; AGFI = .93; TLI = 1.00; CFI = 1.00; RMSEA = .00.

## DISCUSSION

Physical educators have legitimized their subject`s place within curricula by emphasizing the contribution PE can make to students' motor and psychosocial skills as well as their health and well-being [34]. However, what this contribution to pedagogical practice might look like often remains unclear [4]. Therefore, the aim of the present study was to address this issue by developing and evaluating a stress management program specifically designed for the use in regular PE classes. The key findings of this intervention study are that implementing EPHECT in PE can make a positive contribution to the development of adaptive coping skills among vocational students. Most importantly, we found evidence that adaptive coping skills post intervention may act as a mediator for reduced stress perception at a 6-months follow-up.

Three hypotheses were formulated and each of these is now considered in turn. First, it was anticipated that the EPHECT intervention would promote more adaptive and less maladaptive coping post-intervention and this was partly confirmed; students in the IG considerably improved their adaptive coping skills post-intervention when compared to students in the CG. Moreover, findings at the 6-months follow-up show that adaptive coping skills remained relatively stable, even after the intervention has finished. This finding adds to the results of previous coping training programs which have shown small but positive effects on adolescents' adaptive coping skills [20,24,35]. In contrast, no effect was found for maladaptive coping. This might be explained by an increased tendency to listen to the inner self, which is one focus of the coping training. In this respect, students have an increased awareness of both adaptive and maladaptive coping skills. Furthermore, as levels of stress in the present population were not as high as in clinical samples, the motivation to change (e.g., at the behavioral level) could therefore have been rather low. Another explanation is that compared to adaptive coping skills, measurable effects of primary prevention programs on maladaptive coping skills are complex. Studies show that reduced stress levels may have a positive influence on maladaptive coping skills [36,37]. In this respect, possible influences of the coping training on maladaptive coping skills are rather distal outcomes requiring longer-term follow-ups for their detection.

Our second hypothesis was that stress perceptions would be lower at follow-up and this was fully supported. As expected, perceived stress remained stable through the intervention period (from pre to post). These finding echo previous results in which coping training programs have led to a gain in knowledge but have shown no effects with regard to stress symptoms at the end of the intervention [24,19]. Thus, direct effects of primary prevention programs might be restricted to the most proximal outcomes (e.g., adaptive coping), as we have shown with hypothesis 1 [24,38]. Fridrici and Lohaus [24]point out that there could be a time-lagged effect on more distal outcomes, such as stress perception. This supports the need for studies with at least medium-term follow-up assessments. In the current study we addressed this issue by conducting a 6-month follow-up both to gather information about the stability of coping skills and to detect possible medium-term effects on stress perception. As noted above, students reported a slight, but non-significant, decrease in adaptive coping scores 6 months after the coping training finished. However, adaptive coping skills remained higher than pre-intervention and higher than in the CG at follow-up. Most importantly, although all students were in the middle of the exam period during follow-up measurements, student in the IG reported decreased stress levels, whereas a trend toward an increase was found in students in the CG. The findings are in line with previous literature on school-based stress management programs and coping training, which are effective in enhancing coping skills and reducing stress symptoms [26]. However, the mechanisms by which our PE-based coping training may contribute to reduced stress perception remains to be resolved. Several studies on adolescents have shown that adaptive coping strategies can protect an individual from negative consequences caused by adversity or stress and can improve psychological well-being [39,40].

Consequently, we proposed a (heuristic) model in hypothesis 3 in which we expected that the intervention would have an indirect effect on stress perception at follow-up via improved adaptive coping skills post-intervention. The path analysis, as shown in Figure 8.2, supports this prediction. In statistical terms, the effect may be small. However, the positive findings are encouraging considering that stress also depends on the work environment and family climate while PE only makes up a little part of adolescent life. Moreover, it should be noted that the effects of primary prevention programs with participants in the normal psychological range are less distinctive than in secondary preventive programs. The diversity in methodological quality and outcome assessment in previous school-based primary prevention programs targeting stress and coping have produced rather small and heterogeneous effects for stress [26]. However, primary prevention programs to foster adolescents' adaptive coping skills are urgently needed at this early stage in order to reduce the negative consequences associated with chronic stress exposure [24,41]. The findings of a recent study on Swiss vocational students corroborates this demand as one third of this population were already indicating mild school- and job-related burnout symptoms, whereas 16 % showed strong, and 7 % even clinically relevant, symptoms [42].

A major strength of the present study is that the intervention uses a new experience-based approach in conveying psychological theory to adolescents attending vocational schools. It allows students to experience their stress-responses directly and to experiment with different coping strategies in a PE class. Another strength is that the program is implemented by the PE teachers on their own. As mentioned previously, most school-based coping training programs are taught by psychologists or trained study personnel [19,20]. The advantage of implementing the program through PE teachers is that the course of the lesson is barely affected (contents of the program are designed for different sports and can be integrated into regular motor skill training). A smooth integration might play an important role for school principals and teachers in deciding on the longitudinal health interventions to be implemented within their curriculum. Furthermore, sooner or later the question of long-term funding arises for most intervention programs. The provision of intervention materials, an online platform and workshops enables PE teachers to implement the coping training on their own. Fostering adolescents' resilience could therefore become part of the regular PE curriculum.

Despite these positive findings, several considerations warn against their over-generalization. First, the sample was based on adolescents who attended a vocational school in the German-speaking part of Switzerland, and they are therefore not representative of the entire population of vocational students in Switzerland (which also includes, for example, students in the French-speaking part of the country) or in other German-speaking countries with a similar VET system. More research is needed to determine whether similar findings apply to the latter and other dual VET systems across the world. Second, the coping program was closely monitored by a passive observer, and the possible influence of this observer has not been controlled for here.

## CONCLUSION

This study adds to the current debate in the literature on health-oriented PE and on how different countries have incorporated mental-health in their PE curricula. We were able to show that this unique PE-based coping training can be an effective method for promoting vocational students' adaptive coping skills. Moreover, our analyses support the assumption that having an appropriate coping repertoire helps to reduce stress symptoms in the medium term, which hopefully also plays a role in reducing the long-term risk for stress-related diseases.

Such a program can be particularly helpful for adolescents starting out on their professional lives and who might be faced with new challenges and exposed to novel stressors. More research is needed to determine whether the positive findings of the coping training are based on the practical experiences obtained in PE class followed by a short reflection with the teacher and consolidated through the student booklet, or on the introduction of theory and homework tasks by the booklet itself.

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# CHAPTER 9

## Synthesis, discussion and perspectives

Stark increases in adolescent stress and its accompanying negative consequences have increased government attention of schools as an ideal setting for promoting resilience. At the same time, the promotion of mental health within PE is almost universally used to legitimize its place in the school curriculum, however, it is usually absent from PE teacher education. Therefore, we developed, implemented and evaluated a coping training program specifically designed for implementation in PE class.

Based on the background and aforementioned aims of this thesis, as outlined in Chapter 1 and Chapter 2, the following first part summarizes the main results of this PhD thesis, which were particularly discussed in Chapter 4 to 8. Likewise, the discussion will focus on some methodological issues, which, in the framework of a peer reviewed article, can often not be fully described. Finally, this PhD thesis will conclude with an outlook on the future prospects of EPHECT.

## SUMMARY OF THE MAIN RESULTS

### PA and sleep – is the relationship moderated by the methodology of assessment?

Literature reviews elucidate upon theoretical models that could explain potential positive effects and confounds of physical activity on sleep [1–4]. However, a systematic review or meta-analysis uniquely focusing on the methodology of assessment has yet to emerge, particularly among mid-adolescence to early adulthood. Therefore, the first part of this thesis was to conduct a systematic review and meta-analysis of 21 studies, with 16,549 participants in the age range 14–24 years, which showed that higher physical activity levels were positively related with better subjective and objective sleep quality/efficiency, confirming data from other studies [1,2,5,6]. However, most studies were designed as cross-sectional analyses or using subjective measures. Few studies assessed sleep and physical activity using validated and accepted instruments [7–9]. Among the sparse studies that assessed sleep objectively, none of them used accelerometers, although both physical activity and sleep can be assessed using this instrument. Some studies defined subjective sleep duration as subjective sleep quality, despite reports that the two correlate weakly, if at all, in adolescents [10,11]. In summary, current knowledge of best practices in assessing sleep and physical activity in each research field has rarely been applied. As evidenced in the literature, these methodological problems might be the reason for the variability in results and the poor correlations between physical activity and sleep duration [11,12]. Nevertheless, adolescents with higher subjective and objective physical activity levels are more likely to have better sleep.

In studies prior, we learned that assessing either sleep quality or sleep duration imposes unique ramifications for inter-study comparisons. Moreover, a comparison between studies using different questionnaires might be difficult, which reduced the homogeneity of data of all subgroups in the meta-analysis, thus controlling for cofounders was impossible. Since most studies evaluated physical activity and sleep with subjective measures and only one study used subjective and objective assessment for both, namely Lang et al., 2013[2], one aim in this meta-analysis was inconclusive. That is, whether the assessment method has a significant influence on the outcome. Thus, future studies are needed to address this question.

The majority of studies in the literature found a positive correlations between physical activity and sleep by using subjective assessments [13–16], yet studies using objective assessments failed to detect such clear correlations [16–18]. Our first EPHECT study (EPHECT I) showed that in Swiss VET students, higher subjective and objective physical activity levels were positively correlated with better subjective and objective sleep and that males were more active than females. Although adolescents over-estimated their physical activity levels, we confirmed previous reports aligning with our hypothesis that objective and subjective physical activity are moderately correlated, and this correlation was stronger for vigorous than moderate physical activity [7,19]. In respect to the comparison of subjectively and objectively assessed sleep, we could not confirm our hypothesis that the two correlate, instead, our findings were consistent with the literature, revealing weak and inconclusive relationships [20,21]. The fact that similar findings were reported for people with insomnia [22–24], while our study was done with healthy adolescents, highlights the importance of using both subjective and objective assessment tools when investigating correlations between physical activity and sleep. Another explanation for poor correlations between subjective and objective sleep might be due to the fact that the questionnaires evaluated habitual sleep while the objective measures assessed sleep in one night. Results from only one night's sleep might differ from habitual sleep due to a number of varying factors including daytime food, caffeine and alcohol intake, daytime activity, first-night effect caused by the measuring device, etc. On the other hand, Lauderdale et al. [20] reported that sleep variables of a single night collected from wrist actigraphy, sleep logs, and standard sleep questionnaires were only slightly more accurate than reports of habitual sleep. However, unlike eyes, which detect and process visual stimuli, we lack a specific organ or system that can detect or measure sleep quality. Therefore, the choice of methodology to assess sleep patterns may impact the reliability of findings.

Interestingly, our data on the relationship of physical activity and sleep showed that subjective physical activity levels predicted good sleep quality better than objective physical activity levels, which could be due to complicated psychological processes including attention, perception, memory, reasoning, beliefs, attributions, and the assumption of better sleep post-exercise. Moreover, different levels of baseline fitness could lead an unfit person to become more exhausted with less physical activity than a fit person. In other words, it is possible that physical exhaustion is the parameter that induces better sleep, and

[2] Both publications, the meta-analysis (Publication 1) and Publication 2 (Lang et al. 2013) developed in parallel.

therefore, a fit person needs more physical activity to experience the same sleep-inducing effect as an unfit person who becomes physically exhausted faster. However, neither physical exhaustion nor fitness was assessed in our study, but they would be interesting to examine in future studies. It should be pointed out, however, that physical fitness is a physiological attribute that is not only influenced by PA, but also depends on sex, age, genotype and other behavioral determinants [19,25]. Lindwall et al. [26] showed that self-rated physical activity and fitness level may act independently on mental health outcomes, and that the patterns of association between physical activity and mental health may be different from the association between fitness and mental health [26,27].

**EPHECT intervention – an effective approach to teach coping skills in PE class?**

*Findings from the pilot-study EPHECT I*

Another EPHECT I goal was to investigate, whether VET students at risk (low satisfaction with life, poor coping skills, high stress perceptions, and poor sleep quality[3]) would benefit from the EPHECT I intervention in these areas. Moreover, EPHECT I is a useful means for PE teachers to effectively translate the complying psychological theory into regular PE practice. While the study struggled with teacher compliance and overall effectiveness remained undetected, it did have a positive impact on the reduction of maladaptive coping in the subset of adolescents with low baseline life-satisfaction. Reducing maladaptive coping strategies is an important endeavor among adolescents because compared to healthy controls, people diagnosed with depression more often report dysfunctional coping strategies such as avoidance and denial [28]. On the other hand, maladaptive coping strategies constitute a significant risk factor in the development of adolescent depression [29], and are closely associated with self-harm [30].

Interestingly, further results of EPHECT I showed no significant effects on adaptive coping skills, quality of sleep, or perceived stress levels. Since implementation rates were a limitation of this study, students of the intervention group were subdivided (post-hoc) into those with higher and those with lower implementation rates. Still, when comparing the high implementation rate group to the control group, no significant impact was detected of the coping training program on these parameters.

A comprehensive responder analysis in preparation of publication 3 (Chapter 6) revealed that students at risk (low adaptive coping behavior) receiving a medium-high implementation rate showed improved adaptive coping skills post-intervention. Although

[3] Whilst perceived sleep quality was not in the scope of publication 3, this outcome was assessed as part of EPHECT I and is presented here due to its relevance to the PhD thesis.

students with high baseline adaptive coping skills gradually reported lower skills over the course of the school year, their coping was maintained to a much greater degree than for those students receiving a medium-high implementation rate (see appendix table B). This is a promising finding in two respects. First, the differentiated analyses indicated the potential of the EPHECT intervention to teach new coping skills if completely and correctly implemented. Second, the acquisition of appropriate coping skills has potential to reduce future stress levels [31,32].

In turn, stress and quality of sleep might depend on factors outside the scope of the EPHECT intervention. Such confounding variables include work environment, family climate, relationship with peers, etc. [33], which might contribute to the non-significant findings. Another explanation is the fact that the majority of our study subjects reported low or moderate stress levels and sufficient sleep. Due to ceiling-floor effects of reported stress and sleep, improvement was not detectable. Moreover, EPHECT I was implemented as a whole-school program that could be less effective than class-based programs [34,35]. It has been hypothesized that this, aside from possible ceiling-floor effects, might be due to teacher compliance and motivation issues, which lead to low student compliance and motivation [35]. A well-implemented school-based program has potential effectiveness [36] so, given our compliance problems, the quality of implementation is probably more important than whether the program is school- or class-based. In this light, we believe that mandatory teacher participation might be counterproductive. Instead, improved teacher workshops should be used to highlight the importance of a reflection period with the students after each practical exercise.

*Findings from the follow-up study EPHECT II*

Lessons learned about teacher compliance issues were considered in the follow-up study. EPHECT II compared control and intervention groups within the same VET school and showed considerably better implementation rates and accuracy among teachers and students. Highly motivated teachers taught the exercise tasks and gave their students the opportunity for reflection on the exercise and its similarities to everyday and professional life. The development of adaptive coping skills was positively influenced by this coping training program among adolescents enrolled in the EPHECT II study. Regularly completing one's homework reinforced this effect because it was significantly associated with students' reflection and compliance. However, this fact was moderated by teachers controlling for homework tasks. Thus, our recommendations for future implementations of EPHECT are in accordance with recommendations by others for similar programs [37,38]. Namely, we recommend (a) assurance that teachers control for completion of homework tasks rather than evaluation, because students might not document their individual reflections on sensitive issues if they believe the PE teacher will read it, or (b) integration of the readings and homework tasks into other interdisciplinary school subjects.

In accordance with the findings of EHPECT I, EPHECT II failed to show significant improvement of perceived stress levels and sleep quality post intervention. On one hand, this finding might also be due to a ceiling-floor effect, since most students reported low to moderate stress levels [37]. On the other hand, these findings echo previous results in which coping training programs have led to a gain in knowledge but have shown no effects with regard to stress symptoms at the end of the intervention [39,40]. Thus, direct effects of primary prevention programs might be restricted to the most proximal outcomes (e.g., adaptive coping), as elucidated in publication 7 and 8. Fridrici and Lohaus [39] argue for a time-lagged effect of more distal outcomes, such as stress perception. In other words, it has been shown that primary prevention programs are very effective in preventing future problems [32,38]. One of our hypotheses was, therefore, that on a medium term follow-up of six months, stress levels are reduced compared to controls. In accordance with previous reports in the literature [37,38], this hypothesis was confirmed. Specifically, levels of perceived stress were significantly lower among students of the intervention group six months post-intervention compared to control students at the same time. It is notable that the 6-month follow-up assessment interfered with final exams. Indeed, even six months after the end of the coping training program, adaptive coping skills were significantly better among intervention students compared to control students. The findings confirm results from other studies, which showed that coping training has a moderate, but lasting impact on the coping skills of adolescents [39,41,42]. One possible explanation is that the intervention may have an indirect effect on stress perception at follow-up via improved adaptive coping skills post-intervention. Although substantive effects may be small, the findings are encouraging considering that stress also depends on the work environment and family climate, while PE constitutes a small realm of a VET student's life.

## METHODOLOGICAL ISSUES – DECISIONS AND CHALLENGES

Research is a compromise between what is desired and what is possible in terms of scientific advances. Statistical models are always approximations of reality that use certain assumptions and simplifications. Although we used standardized and validated methods, conducted solid research, and our findings are reasonable in light of current literature, there are limits to the generalizations of the results due to methodological constraints, which require discussion.

### Meta-analysis

The meta-analysis excluded all studies that contained participants with psychiatric, mental, or physical illnesses, because it has been shown that participants who report fair or poor mental health (e.g., depression and sleep deprivation) believe they have slept less than their actual sleep duration [20]. Since other studies suggested a possible indirect influence of gender [43], data extracting included different results for males and females. However, given that only a few studies reported separate results for male and female participants, it was not possible to thoroughly and comprehensively control all studies for gender, which is why it was ultimately not done in the meta-analysis. Likewise, many of the included studies lacked sufficient analysis of further possible confounders, such as age [44], gender [43], daylight exposure [44,45] or mental health [20]. Thus, it was impossible to perform statistical analyses of all subgroups among studies included the meta-analysis, while controlling for these confounders.

The relatively small sample sizes of included studies and the diversity of used methodology did not allow for a meaningful overall meta-analysis. Therefore, only results of the subgroup analyses were interpreted despite the fact that this approach did not fully allow to fulfil the aim of determining methodological influences on the outcomes. Thus, the systematic review and meta-analysis illustrated the problem of comparisons across studies and the interpretation of study results. Additionally, only one study assessed both subjective and objective measures of physical activity and sleep within the same sample, which also limited the fulfillment of the aim to investigate whether the assessment tools influenced the results. Further meta-analyses which place a special focus on possible methodological confounders are needed. Studies might assess athletes vs. non-athletes, high vs. low moderate/vigorous physical activity, exercise vs. non-exercise days, sleep duration vs. sleep quality, cross-sectional vs. pre-post-invention studies, and a combination of subjective and objective assessment tools. Such results will advance the body of knowledge regarding dose-response relationships between regular physical activity and sleep in this age group.

**EPHECT I and II studies**

Both studies were designed to measure stress, PA, coping skills, and sleep in adolescents. The studies measured VET students from the second grade on (EPHECT I) or first-grade students (EPHECT II). Both groups are a representative sample of adolescent VET students from Switzerland who must cope with the dual responsibilities of academic and professional demands and are therefore a good population to study coping skills and stress in this age group. Moreover, the EPHECT intervention was specifically designed to be implemented in PE classes among this population.

However, one of the biggest problems of EPHECT I was the poor adherence to the EPHECT protocol by some of the teachers, which also led to low compliance among their students. Indeed, reflection periods especially initiated by the PE teacher are a core element of EPHECT. Given the poor teacher adherence to this vital component of the intervention, overall effectiveness remained undetected. Additionally, the correct use of the student workbook, in conjunction with the experiences obtained in PE, was not fully explained to students of several classes. According to the teachers, only 3 % of the students completed all required readings, self-tests, and reflection tasks. Seventy percent of the students worked at least a little with the workbook. This is consistent with the student evaluation, in which 3% indicated to have completed all or almost all required tasks, 27% worked at least a little with the workbook, and 70% indicated they took a short look or did not work with the workbook at all. However, valid data on the student evaluation were only available for 164 students. Summing up, only 2% of these students reached a high implementation rate, while 9% indicated a moderate to high implementation rate. A low to moderate implementation rate was at least reached by 37%, while the remaining 52% scored low. However, according to the students, only 3% of the teachers delivered the program at a two-week rhythm, as intended by the EPHECT I coping training program. Thirty-six percent indicated only one or two lessens referring to stress management, while 29% indicated they did not receive the program at all. This is in contrast to the teacher evaluation, in which 80% of the teachers indicated they have implemented all (40.0 %) or almost all (43 %) modules of the stress management, 13% barely implemented the program and 5% not at all. It is, therefore, not a surprise that teachers indicated that only 25% of the students were interested in the coping training and enjoyed the intervention. Nevertheless, the teachers also recognized a substantial knowledge gain in 30% of the students.

The practical and implementation problems with EHPECT I led to the creation of the improved training program EPHECT II (voluntary participation of teachers, improved workshop and support throughout the intervention) and EPHECT III (revised intervention materials). In addition, there are a few methodological points to discuss. While, several classroom-based coping programs can have positive results [33,34,36,41], EPHECT was specifically designed as a PE-based program to break the routine of normal classroom lessons. The theoretical information in each module is connected with a specific experience made previously during a PE class. However, whether the effects found in the studies above are due to the experienced-based approach in PE class, the student workbook, or both cannot be fully answered, as there were no control groups receiving the contents solely in a PE or regular classroom setting. In other words, this prevented the investigation whether delivering the program as part of the PE class had a direct influence or advantage. However, presenting the theory without the procedural practical experience would correspond to a truncation, which is incompatible with the underlying idea of experiential learning. Further, any other coping training program used for a control group would have been substantively different from the EPHECT intervention, which would have rendered direct comparisons between these groups.

## OUTLOOK

> *You need to be able to manage stress because hard times will come, and a positive outlook is what gets you through.*
>
> Marie Osmond

PE time is a limited resource for VET students, however, for these students, even normal classroom time is very brief, restricted to only one or two days per week. Adding a classroom-based coping program would necessarily take some time away from other subjects. However, EPHECT can be a time-efficient way of integrating a coping program into the lives of VET students who have been shown susceptible to work-related stress, especially when the intervention is implemented among first-grade students who face the transition to a VET school and newly need to balance academic and job-related demands. Implementing EPHECT has the potential of teaching the students coping skills during a particularly vulnerable period of transition in their lives that might benefit them later on during their education when academic and professional requirements and therefore the potential for stress increase. This way, the EHPECT coping training could potentially help in reducing the incidence of burnout and other psychological imbalances and even more serious psychological problems such as depression.

The project shows how physical educators can translate psychological theory into practice and implement both in a meaningful way, as this topic is rarely addressed in PE teacher education. This lack is also responsible for insisting functionalistic understanding of PE in that health-related knowledge is automatically acquired, without explicitly addressing such issues. This is an important point in particular for Swiss VET schools, as their new PE syllabus places a stronger focus on stress management and mental health. Therefore, EPHECT provides PE teachers one possibility on how to fulfill these new requirements.

Several school and education boards have already expressed interest in translated versions of the EPHECT program that is currently only available in German. Plans are to translate it into French and implement it into VET schools in the French-speaking part of Switzerland, which has a very similar background to the German-speaking part. Interest has also been indicated from Finnish and Australian officials.

However, future validation studies should also address second and higher-grade levels as well as other vocational education groups (e.g., forestry workers, industrial clerks, graphic designer) to increase the generalizability of the present results. Beyond vocational education and training, it is also known that university lecturers in Germany have implemented EPHECT among first year sport science and psychology students. Additionally, a former member of the EPHECT-team has just started to implement EPHECT among the project “InTeam” in Basel, which is an integration program (motivation semester) for unemployed adolescents. Additionally, there are also requests to design a PE-based coping training for other school forms (e.g., gymnasium = higher education, university entrance level) or for teachers, an occupational group where burnout rates are increasingly prevalent.

A recent study of the University of Northwestern Switzerland with support from the national science foundation found that one in five teachers feel permanently overstrained [46]. Moreover, to examine whether levels of physical activity influences the outcomes of EPHECT would shed further light on the stress-buffering effect of physical activity among VET students. As females of this age group are less physical active than males, it would be interesting to assess to what degree gender influences this relationship.

Another important point for updated future versions of EPHECT is to increase the focus on sleep hygiene. The current program mainly concentrates on the development of adaptive coping skills with only little attention on sleep hygiene. Since sleep deprivation can exacerbate or even cause physiological and psychiatric problems [47], putting a spotlight on sleep hygiene in future versions of EPHECT is expected to further increase its positive impact on the lives of young VET students.

> *There is a time for many words, and there is also a time for sleep.*
>
> Homer

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# APPENDIX

# Additional Analyses EPHECT I

**Table A: Appendix - Responder analyses EPHECT I**

*Inferential statistics for group (IG n=353 vs. CG n=430), time (pre- vs. post intervention), implementation rate (none (n=0 CG) vs. low (n=28) vs. low-moderate (n=195) vs. moderate-high (n=130) and risk factor (above vs. below median split of each variable); N=864*

| | Group | | Time | | Group x time | | Implement x time | | Group x risk factor x time | | Risk factor x time | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variables | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ | $F$ | $\eta^2$ |
| Adaptive coping | .541 | .001 | .236 | .000 | .001 | .000 | 1.338 | .005 | 4.87* | .006 | 131.74*** | .133 |
| Emotion-focused coping | .040 | .000 | 4.924* | .006 | .152 | .000 | 1.429 | .005 | .195 | .000 | 201.48*** | .189 |
| Problem-focused coping | 1.192 | .001 | 5.154* | .006 | .110 | .000 | .940 | .004 | .387 | .000 | 151.32*** | .149 |
| Maladaptive coping | .135 | .000 | 6.272* | .007 | .005 | .000 | .171 | .001 | 2.387 | .003 | 140.31*** | .140 |
| Perceived stress | .354 | .000 | .637 | .001 | 1.42 | .002 | .673 | .003 | .420 | .000 | 100.93*** | .105 |
| Sleep quality | 6.555* | .004 | .898 | .001 | .946 | .001 | 1.804 | .007 | 2.630 | .003 | 156.48*** | .154 |

*Notes.* IG = intervention group; CG = control group. *M* = mean; *SD* = standard deviation. *$p < .05$. **$p < .01$ ***$p < .001$.

On average, the IG students who reported low *perceived stress* on pre-test (below median split) showed increased *stress* on post-test regardless of their program implementation level. In contrast, students reporting high *perceived stress* on pre-test (above median split) revealed decreased *stress* on post-test regardless program implementation level. Nevertheless, *perceived stress* decreased in both IG and CG, thus no significant effect could be reported as a result of the EPHECT program. *Maladaptive coping skills* showed no differences between IG and CG. In contrast, students with high pre-test *maladaptive coping* scores showed reduced scores at follow up, independent of implementation rate (non-significant). No significant effects emerged for *sleep quality*.

The students reporting lower pre-test *adaptive coping skills* also revealed increased *adaptive coping* in post-test when they received a low-medium or medium-high EPHECT implementation rate. There was a non-significant trend towards increased *adaptive coping skills* in CG students below the median split. Students receiving the EPHECT intervention with a low implementation rate showed a decrease in *adaptive coping* scores. Students above the median split in both groups showed decreased *adaptive coping* skills post-test, but to a lesser degree for students receiving a high implementation rate. In summary, intervention students with lower pre-test *adaptive coping* skills reported a significant improvement in *adaptive coping* post-test compared to controls $F(2,862) = 4.87$, $p < .05$, $\eta^2 = .006$.

# Contribution to the PhD project

**Table B: Appendix - Contribution to the PhD project**

| **Topic** | **Time** | **Contribution by the PhD student** | **Contribution by other members of the EPHECT Team** |
|---|---|---|---|
| Submit research proposal BASPO | 2009 | | PD Dr. Markus Gerber<br>Dr. Tim Hartmann<br>Prof. Dr. Uwe Pühse |
| First draft of intervention program and booklets (student/teacher) | 2009-2010 | | PD Dr. Markus Gerber<br>Dr. Tim Hartmann |
| First teacher workshop | 2010 | | PD Dr. Markus Gerber<br>Dr. Tim Hartmann |
| Apply for ethical approval | 2010 | Begin work by PhD student. Wrote application to EKBB based on the BASPO research proposal. | |
| Contact control school | | | PD Dr. Markus Gerber |
| Construct and develop teacher manual and student workbook | 2010 | Based on the first idea of PD Dr. Markus Gerber, PhD student and colleague, Mirjam Lüthy, wrote an 8-module workbook customized for students and a manual with specific exercises for teachers. Final drafts revised by PD Dr. Markus Gerber and layout professionally formatted by outsourced graphic designer. | Mirjam Lüthy<br>Constanze Klesse (graphic designer) |
| Website creation for students and teachers | 2010 | The PhD student creates a homepage for students via iWeb.<br>Together with Mirjam Lüthy the PhD student records several exercise tasks for the teachers, which are uploaded on www.gymfacts.ch. | Mirjam Lüthy |
| Second teacher workshop | 2010 | PhD student and colleague Mirjam Lüthy organize and conduct second workshop at intervention school. | PD Dr. Markus Gerber<br>Mirjam Lüthy |

**Table B continued**

| Topic | Time | Contribution by the PhD student | Contribution by other members of the EPHECT Team |
|---|---|---|---|
| Prepare EPHECT I questionnaire | 2010 | Translation of DBAS-16 (Morin et al. 2007). | PD Dr. Markus Gerber<br>Mirjam Lüthy |
| Collect pre-intervention EPHECT I psychological data | 2010 | Preparing informed consent.<br>Data collection from 2000 VET-students from 2 VET-schools with my colleague Mirjam Lüthy. | Mirjam Lüthy |
| EPHECT I data entry and preliminary analysis (cluster analysis of risk profiles) | 2010 | Scanning questionnaires on-site immediately after data collection with Mirjam Lüthy.<br>Data cleansing and integrating into SPSS.<br>Cluster analysis with PD Dr. Markus Gerber to select students from high risk and low risk clusters (stress, coping, sleep, PA) for subgroup measurements. | PD Dr. Markus Gerber<br>Mirjam Lüthy |
| Recruit participants for physio measurements EPHECT I | 2010 | Recruiting 56 adolescents from two vocational schools. | Mirjam Lüthy |
| Collect and coordinate T1 EPHECT I physiological data | 2010-2011 | Coordinating data collection (participants located around Zürich, attend school only on one day, only 10 SomnoWatches for actigraphy and sleep-EEG, salivary cortisol) with Mirjam Lüthy.<br>Coordinating laboratory analysis (sleep-EEG, cortisol). | Mirjam Lüthy |
| Create homepage for students and teachers | 2010 | The PhD student creates a homepage for students via iWeb<br>Together with Mirjam Lüthy the PhD student records several exercise tasks for the teachers, which are uploaded on www.gymfacts.ch. | Mirjam Lüthy |
| Collect EPHECT I psychological data post-intervention | 2011 | Colleague Mirjam Lüthy resigns and PhD-student, organizes T2 post-intervention measurements. New colleague Anne Karina Feldmeth aids in collecting and scanning questionnaire data of 2000 VET-student from two VET-schools. | Anne Karina Feldmeth |
| Collect and coordinate T2 EPHECT I physiological data | 2011 | Coordinate data collection (participants located around Zürich, attend school only one day, using 10 SomnoWatches for actigraphy and sleep-EEG, salivary cortisol).<br>Coordinate laboratory analysis (sleep-EEG, cortisol). | |
| Analyze EPHECT I physiological data | 2011 | PhD-student validates cut-off values for moderate and vigorous physical activity (SomnoWatch) and visually analyzes raw actigraphy data of 56 participants. | Marielle König, Vladimier Djurdjevic (sleep-EEG)<br>University of Trier (Cortisol) |

**Table B continued**

| **Topic** | **Time** | **Contribution by the PhD student** | **Contribution by other members of the EPHECT Team** |
|---|---|---|---|
| Full data entry, control and cleaning of all EPHECT I measurements in SPSS | 2011-2012 | Clean and integrate T2 psychological data into SPSS<br>Entry of physiological data (sleep-EEG, cortisol, actigraphy) into SPSS.<br>Match two data files (pre- and post-intervention). | |
| Write research proposal for follow-up study (EPHECT II) | 2012 | Based on EPHECT I experiences (low teacher compliance), PhD student initiates follow-up study with qualitative data assessments. Colleague, Anne Karina Feldmeth, agrees to psychological data collection. PhD student writes PhD-proposal to „Gesundheitsförderung Schweiz – Fonds innovative Projekte". Anne Karina Feldmeth and PD Dr. Markus Gerber edit and approve final version of the research proposal. The project won 2012 funding round with 27,107.00 CHF. | Anne Karina Feldmeth<br>PD Dr. Markus Gerber |
| EPHECT II participant recruitment | 2012 | Anne Karina and PhD student randomly selected classes for participation in the quantitative psychological measurements.<br>PhD student recruits eight voluntary VET-students for qualitative interviews. | Anne Karina Feldmeth |
| Conduct and organize teacher workshop and data assessment pre-intervention EPHECT II | 2012 | Teacher workshop organized and conducted by PhD student.<br>Qualitative interviews executed by the PhD student.<br>Quantitative data (N = 140) collected together with Anne Karina Feldmeth. | Anne Karina Feldmeth |
| Weekly classroom supervision of intervention group EPHECT II | 2012-2013 | PhD student conducts weekly classroom observations in intervention classes. Passive classroom observation with a semi-structured observation protocol. Aimed to collect information about the feasibility and acceptance by the students and teachers. PhD student supported by two master's students (she served as supervisor) to observe four 90-minute classes per week. | Two master students |
| Transcribe qualitative interviews and recordings of EPHECT II classroom observations | 2012-2013 | Transcription of 2 x 8 qualitative interviews (20 hours) and recordings of the discussion during the classroom observations (6 hours) supported by the two master students. | Two master students |
| Collect EPHECT II quantitative data post-intervention | 2012 | Together with colleague, Anne Karina Feldmeth, PhD student organized and conducted quantitative data assessment post-intervention. | Anne Karina Feldmeth |
| Collect EPHECT II quantitative data at follow-up | 2013 | After Anne Karina Feldmeth resigned, follow-up assessments were planned and conducted independently by PhD student. | |

**Table B continued**

| Topic | Time | Contribution by the PhD student | Contribution by other members of the EPHECT Team |
|---|---|---|---|
| Entry, control and cleaning EPHECT II data | 2012-2013 | Data management of quantitative assessments pre- and post-intervention together with Anne Karina Feldmeth, while follow-up data were managed independently by the PhD student. | Anne Karina Feldmeth |
| Analyze EPHECT II qualitative data | 2013-2014 | PhD student and two master's students analyzed qualitative data. Classroom observation data were fully analyzed to collect important information regarding prompt revision of the EPHECT program. | Two master students |
| EPHECT program and intervention material revision | 2013-2014 | PhD student planned, organized and conducted an expert meeting to evaluate intervention materials. She invited experts across different disciplines: PE-teachers from VET-schools, sport scientists, mental health coaches, sport psychologists, and psychologists for children and adolescents. PhD student moderated the workshop based on the results from the qualitative data assessments (interviews, classroom observations). She combined expert opinions and revised workbook for students and the manual for teachers accordingly. | Expert group, including<br>PD Dr. Markus Gerber<br>Dr. Tim Hartmann<br>Mischa Stillhart |
| Write research proposal to finance revision and promotion of the EPHECT-program (EPHECT III) | 2013 | PhD student applies for grant from Swiss Federal Office of Sport (FOSPO) „Subventionskredit Schulsport“. PD Dr. Markus Gerber edits and approves final version of research proposal. Project secures funding of 80,000.00 CHF. | PD Dr. Markus Gerber |
| Create new webpage for students and teachers | 2014 | Together with IT-Expert, PhD-student creates research-based EPHECT webpage for students and teachers. Receive several requests to use website internationally. Webpage translated into English by PhD student. | IT-expert |
| National Workshops for PE teachers at VET-schools | 2014-2015 | Together with Mischa Stillhart (PE-teacher at a VET-school and head of “Physical Education at VET-schools” at the Swiss Federal Office of Sport (FOSPO/BASPO) the PhD student plans and conducts two EPHECT-Workshops. | Mischa Stillhart |
| Statistical analyses and writing manuscripts of EPHECT I and EPHECT II data | 2012-2015 | All statistical analyses of the four EPHECT-manuscripts for PhD thesis (first author) executed by PhD student. Feedback of supervisor and colleagues were supportive. Authors have edit and approve final version of manuscripts for submission to *Physiology & Behavior*, *Journal of Sport and Exercise Psychology*, *Physical Education and Sport Pedagogy*, and *Journal of Teaching in Physical Education*. | Co-authors |

**Table B continued**

| **Topic** | **Time** | **Contribution by the PhD student** | **Contribution by other members of the EPHECT Team** |
|---|---|---|---|
| Meta-analysis | 2012-1015 | PhD student started with a systematic literature search (using PRISMA guidelines) about relationship between adolescent physical activity and sleep. She presented systematic review to Editor of *Sleep Medicine Reviews*, who recommended meta-analysis. Data from all studies were summarized by first author. Nadeem Kalak checked data accuracy. PhD student wrote manuscript, which was read, revised and approved by all authors. | Co-authors |
| Doctoral training | | Academic training oriented to achieve quantitative and qualitative statistical skills to collect and analyze EPHECT I and EPHECT II data. PhD student completed coursework exceeding requirements for PhD thesis. Detailed course list in curriculum vitae (19 credit points in 12 courses). | |
| Conference abstracts and presentations | 2010-2015 | PhD student presented research at 10 national and international conferences. Her statistical, methodological, writing and presenting skills were polished while foster research network. | |
| Teaching activities | 2010-2015 | Please find the teaching activity list by the PhD student in the curriculum vitae. Some of the teaching activities within the DSBG were specifically related to the PhD project. | |

*Notes*. DBAS = Dysfunctional Beliefs and Attitudes about Sleep Questionnaire, PA = physical activity, PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses, VET = Vocational Education and Training

# Curriculum vitae

**Personal data**

| | |
|---|---|
| Name | Christin Lang |
| Address | Kanderner Str. 24, D-79588 Efringen-Kirchen |
| E-Mail | christin.lang@unibas.ch |
| Date of Birth | 29.09.1983 |
| Citizenship | Germany |
| Family Status | Married, two children |

## Education

| | |
|---|---|
| 03/2010 - present | PhD Student<br>Department of Sport, Exercise and Health (DSBG) University of Basel, Basel, Switzerland |
| 10/2004 - 01/2010 | Magister Atrium in *Sport Science* and *History of Contemporary German Literature*<br>Albert-Ludwigs-University of Freiburg i. Brs., Germany<br>Magister thesis in *Sport Science*: "Sport and learning ability in school aged children: Empirical evaluation of the project Learning in Motion", Solothurn (Switzerland) |
| 09/2001 to 05/2004 | Abitur (general qualification for university entrance, comparable to Swiss Matura).<br>Ernährungswissenschaftliches Gymnasium Lörrach, Germany |
| 08/2001 to 07/2002 | High School Diploma<br>Clay Center Public Schools, Nebraska, USA |

## Academic training during PhD (19 ECTS) and PhD workshops

2011 Statistik & SPSS, DSBG, University of Basel, spring 2011, 4 ECTS.

Körperliche Aktivität und Sport im Rahmen der Psychiatrie und klinischen Psychologie, DSBG, University of Basel, spring 2011, 4 ECTS.

21. DVS-Nachwuchsworkshop für sozial- und geisteswissenschaftliche Teildisziplinen, University of Würzburg (Germany), December 08th-10th 2011.

2012 Einführung in die Strukturgleichungsanalyse mit AMOS, University of Freiburg (Germany), spring 2012, 1 ECTS.

Qualitative Forschungsmethoden, DSBG, University of Basel, spring 2012, 3 ECTS.

Qualitative Interviewforschung, University of Freiburg (Germany), spring 2012, 1 ECTS.

Rekonstruktive Analyse qualitativer Interviews - Hermeneutische und kategorisierende Verfahren in der sozialwissenschaftlichen Textanalyse“, Basel, Hochschule für Soziale Arbeit FHNW, fall 2012, 1 ECTS.

Nachwuchs-Satellitentagung der DVS-Sektion Sportpädagogik, Swiss Federal Institute of Sports Magglingen (Switzerland), June 6th-7th 2012, „Forschungsmethoden und international Publizieren“.

2013 Präsentation empirischer Studien, Fernuniversität Hagen (Germany), winter 2012/13, 3 ECTS.

Forschungsmethoden der Psychologie, Fernuniversität Hagen (Germany), winter 2012/13, 2 ECTS.

22. DVS-Nachwuchsworkshop für sozial- und geisteswissenschaftliche Teildisziplinen, Institute of Exercise and Health Sciences, University Basel (Switzerland), February 11th-13th 2013.

Asp-Nachwuchsworkshop zur 45. Jahrestagung der asp, “EEG-Messungen in der Sportwissenschaft”, University of Halle (Germany), May 7th-9th 2013.

Nachwuchs-Satellitentagung der DVS-Sektion Sportpädagogik, University of Hamburg (Germany), May 29th-30th 2013, „Kontroversen zwischen erkenntnistheoretischen Positionen und deren „Wege“ der Erkenntnisgewinnung“.

## Employment History & Professional Experience

| | |
|---|---|
| 03/2010 to present | Research Assistant<br>Department of Sport, Exercise and Health (DSBG) University of Basel, Basel, Switzerland<br>✓ PhD thesis as a part of the EPHECT study: Expertise in planning and conducting a large school-based intervention study (EPHECT I) and a smaller follow-up study (EPHECT II), qualitative and quantitative data evaluation and analysis, data management and analysis, conducting expert and teacher workshops to make revisions on and properly execute the EPHECT stress management intervention among Swiss vocational schools (EPHECT III), presentation of conference abstracts and other research projects.<br>✓ Advanced training in statistics, including SPSS, structural equation modelling with AMOS, qualitative research methods, reconstructive analysis of qualitative interviews, and research methods in psychology.<br>✓ University teaching activities, supervision of master's thesis, internal presentations.<br>✓ Journal Reviewer (Journal of Adolescence, Neuropsychiatric Disease and Treatment, Physiology & Behavior, Stress & Health, Sportwissenschaft) |
| 10/2007 to 03/2008 | Trainer at the University Sports Centre in "apparatus gymnastics" (open to all students and performance level)<br>University of Freiburg, Freiburg, Germany |
| 03/2007 to 03/2008 | Trainer at the University Sports Centre in "Weight Training for Beginners"<br>University of Freiburg, Freiburg, Germany |
| 04/2000 to 07/2008 | Laboratory Assistant, Research and Development Department, *Endress & Hauser*, Maulburg, Germany |

## Awards

02/2014 — 1st Place "Young Researchers' Award" of the Swiss Sport Science Association (SGS), Section: Social Sciences, 6th Annual Congress of SGS, University of Fribourg/Freiburg, (Switzerland), February 13, 2014.

02/2013 — 2nd Place "Young Researchers' Award" of the Swiss Sport Science Association (SGS), Section: Social Sciences, 5th Annual Congress of SGS, University of Basel, (Switzerland), February 14, 2013.

07/2013 — 2nd Place "Poster Award" of the AIESEP International Conference 2013, University of Warsaw (Poland), July 4 -7 2013, "Physical Education and Sport: Challenging the Future".

## Research Funding

01/2013 — Health Promotion Switzerland - Funding for innovative projects. "Stress management in physical education class". (Project ID: IP18.15) CHF 27,107,-

12/2013 — Funding for physical education – Commission physical education, Swiss Federal Office of Sport (FOSPO/BASPO). "Stress management in physical education class for vocational students" (Project ID: BASPO VM – 100,189) CHF 80,000,-

11/2015 — Early Postdoc Mobility, Swiss National Science Foundation. "Acute and short-term exercise effects on the circadian rhythm of adolescents with extreme-evening type circadian preference: A novel treatment to improve sleep health" (Verfügung 2BSP1_165373) CHF 96,750,-

## Teaching Activities - University of Basel (DSBG)

Research methods in social sciences (DSBG, 2010 to 2012)

- "Ethics in Research"

Scientific work - personal skills (DSBG, 2012 to 2013)

- "Dealing with Scientific Literature"
- "Ethical Aspect of Scientific Writing"

Topics of sport pedagogical research (DSBG, 2010 to 2015)

- "EPHECT-Study: Effects of a Physical Education based Coping Training"
- "Learning in Motion"

Foundations in sport pedagogy (DSBG, 2010 to 2015)

- "Embodiment & Learning in Motion"
- "Mental Health in Physical Education – EPHECT-study"

Child and adolescent development and sport participation (DSBG, 2013)

- "Psychosocial Aspects of Physical Change"
- "Ego Development"
- "The vulnerable Period of Life"

Foundations of scientific work (DSBG, 2014, 2015)

- "Formulating a scientific research questions, developing a search strategy"

Mental processes in sport (DSBG, 2015)

- EPHECT – How to translate psychological theory into PE practice. An experiential approach

Sport pedagogy in non-school settings (DSBG, 2015)

## Journal Reviews

- Journal of Adolescence (IF = 1.88)
- Neuropsychiatric Disease and Treatment (IF = 2.15)
- Physiology & Behavior (IF = 3.16)
- Sportwissenschaft
- Stress & Health (IF = 1.34)

## PUBLICATION LIST

### Peer Reviewed Articles

2015

**Lang, C.**, Kalak, N., Brand, S., Holsboer -Trachsler, E., Pühse, U. & Gerber, M. ( 2015 /in press). The relationship between physical activity and sleep from mid adolescence to early adulthood. A systematic review of methodological approaches and meta-analysis. *Sleep Medicine Reviews.* (IF 2015: 8.51)

**Lang, C.**, Feldmeth, A.K., Brand, S., Holsboer-Trachsler, E., Pühse, U. & Gerber, M. (2015 / accepted). Stress management in physical education class: An experiential approach to improve coping skills and reduce stress perceptions in adolescents. *Journal of Teaching in Physical Education*. (IF 2015: 0.48)

Gerber, M., **Lang, C.**, Feldmeth, A.K., Elliot, C., Brand, S., Holsboer-Trachsler, E., Pühse, U. (2015). Burnout and mental health in Swiss vocational students: The moderating role of physical activity *Journal of Research on Adolescence*, 25, S. 63-74. (IF 2014: 2.51)

Elliot, C., **Lang, C.**, Brand, S., Holsboer-Trachsler, E., Pühse, U., Gerber, M. (2015 / in press). Burnout symptoms among adolescents above versus below current recommendations for vigorous physical activity: An exploratory study with vocational students. *Journal of Sport and Exercise Psychology*. (IF 2014: 2.59)

Gerber, M., Lindwall, M., Brand, S., **Lang, C.**, Elliot, C., Pühse, U. (2015 ). Longitudinal relationships between perceived stress, exercise self - regulation and exercise involvement among physically active adolescents. *Journal of Sports Sciences*, 33, 369-380. (IF 2014: 2.10)

Gerber, M., Feldmeth, A. K., **Lang, C.**, Brand, S., Elliot, C., Holsboer-Trachsler, Pühse, U. (in press). Mental toughness reduces symptoms of burnout among adolescents with elevated stress levels. A longitudinal study with vocational students. *Psychological Reports.* (IF 2015: 0.53)

2013

**Lang, C.**, Brand, S., Feldmeth, A.K., Holsboer-Trachsler, E., Pühse, U. & Gerber, M. (2013). Increased self-reported and objectively assessed physical activity predict sleep quality among adolescents. *Physiology & Behavior*, 120: 46-53. (IF 2012: 3.16)

Gerber, M., **Lang, C.**, Feldmeth, A.K., Elliot, C., Brand, S., Holsboer - Trachsler, E., & Pühse, U. (2013). Burnout and mental health in Swiss vocational students: The moderating role of physical activity. *Journal of Research on Adolescence*, 54, 808-814. (IF 2012: 2.70)

Gerber, M., Brand, S., Feldmeth, A. K., **Lang, C.**, Elliot, C., Holsboer - Trachsler, E., & Pühse, U. (2013). Adolescents with high mental toughness adapt better to perceived stress: A longitudinal study with Swiss vocational students. *Personality and Individual Differences*, 54, 808-814. (IF 2012: 1.88)

## Monographs

2014

Gerber, M., **Lang, C.**, Lüthy, M. (2014). *Stressmanagement im Sportunterricht. Ein Trainingsprogramm in 6 Modulen. Trainingsheft für Lernende an Berufsfachschulen* [Stress management in physical education class. A coping training with 6 modules. Workbook for vocational students] (2nd, compl. rev. ed.). Basel: University of Basel.

Gerber, M., Lang, C., Lüthy, M. (2014). *Stressmanagement im Sportunterricht. Ein Trainingsprogramm in 6 Modulen. Trainingsmanual für Sportlehrkräfte an Berufsfachschulen* [Stress management in physical education class. A coping training with 6 modules. Training manual for PE teacher] (2nd, compl. rev. ed.). Basel: University of Basel.

2010

Gerber, M., Hartmann, T., **Lang, C.**, Lüthy, M., Brand, S. (2010). Stressmanagement im Sportunterricht. Ein Trainingsprogramm in 8 Modulen. Broschüre für BerufsschülerInnen , Dübendorf: Helsana Versicherungen AG.

Gerber, M., Hartmann, T., **Lang, C.**, Lüthy, M., Brand, S. (2010). *Stressmanagement im Sportunterricht. Ein Trainingsprogramm in 8 Modulen.* Broschüre für BerufsschullehrerInnen , Dübendorf: Helsana Versicherungen AG.

## In Revision

2015

**Lang, C.**, Feldmeth, A.K., Brand, S., Holsboer-Trachsler, E., Pühse, U. & Gerber, M. (in revision). Effects of a Physical Education-based Coping Training on Adolescents' Coping Skills, Stress Perceptions and Quality of Sleep (EPHECT II). *Physical Education and Sport Pedagogy.* (IF 2015: 0.95)

**Lang, C.** , Brand, S., Holsboer-Trachlser, E., Pühse, U., Gerber, M. (submitted). Teaching stress management in physical education class: A quasi-experimental study with vocational students (EPHECT I). Scandinavian Journal of Educational Research (IF 2014: 0.57)

## Non Peer-Reviewed Articles

2015

**Lang, C.**, & Gerber, M. (2015). Stressmanagement im Sportunterricht (EPHECT). Ein Ansatz zur Stärkung von Bewältigungsstrategien bei Berufssschülern [Stress management in physical education (EPHECT). An approach to reinforce coping strategies among vocational student]. Schule im Blickpunkt, 48, 14-16.

Hartmann, T., Gerber, M., **Lang, C.**, & Pühse, U. (2015). Zeig dem Stress die rote Karte! *Mobile Praxisbeilage*, 11, pp.

## Conference Abstracts and Internal Presentations

2015

**Lang, C.**, Brand, S., Feldmeth, A.K., Holsboer-Trachsler, E., Pühse, U., Gerber, M. The mediating role of coping skills on effects of a coping training in physical education class on adolescents' stress perception. *14th European congress of Sport Psychology (FEPSAC)*, University of Bern, Bern, Switzerland, July 15th 2015.

**Lang, C.**, Kalak, N., Brand, S., Feldmeth, A.K., Holsboer-Trachsler, E., Pühse, U., Gerber, M. The relationship between physical activity and sleep in adolescence. A systematic review of methodological approaches. *14th European Congress of Sport Psychology (FEPSAC)*, University of Bern, Bern, Switzerland, July 16th 2015.

2014 **Lang, C.** Do improved Coping skills mediate the effects of a physical education based coping training on adolescents` stress perceptions?, *6th Annual Conference of the Swiss Association of Sport Sciences (SGS),* University of Fribourg, Fribourg, Switzerland, February 13th 2014.

**Lang, C.** Results of the EPHECT-Study: Prevalence and correlates of self-reported and objectively assessed physical activity and sleep quality among adolescents. Is PE class good for sleep? , *Research Colloquium*, *Department of Sport, Exercise and Health*, University of Basel, Basel, Switzerland, March 15th 2012.

2013 **Lang, C.** Was ist eigentlich die EPHECT-Studie? [What is actually the EPHECTstudy?], *Annual meeting of the Department of Sport Exercise and Health*, University of Basel, Basel, Switzerland, February 8th 2013.

**Lang, C.** Effects of EPHECT: The relationship between exercise, sleep complaints and psychological well-being among vocational-students, participating in a P.E. based coping training versus students of a control school , 22nd. *DVS-workshop for young researchers in social sciences*, Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland, February 11th 2013.

**Lang, C.**, Feldmeth, A. K., Brand, S., Holsboer-Trachsler, E., Pühse, U., Gerber, M. Self-reported and objectively assessed physical activity and sleep quality among adolescents. Is P.E. class good for sleep?, *5th Annual Conference of the Swiss Association of Sport Sciences (SGS)*, University of Basel, Basel, Switzerland, Februar 14th 2013.

**Lang, C.** Effekte eines Schulsport basierten Stressmanagement Trainings auf die Stresswahrnehmung und Bewältigungskompetenzen. Ergebnisse der Pilot- und Followup Studie, *ASP-workshop for Young Resea*rchers, Martin-Luther-University, Halle-Wittenberg, Germany, May 8th 2013.

**Lang, C.**, Feldmeth, A. K., Brand, S., Holsboer-Trachsler, E., Pühse, U., Gerber, M. Effekte eines Schulsport basierten Stressmanagement Trainings auf die Stresswahrnehmung und Bewältigungskompetenzen , *45th Annual Conference of the German working community of Sport Psychology (ASP).* Martin-Luther-University, Halle-Wittenberg, Germany, May 11th 2013.

**Lang, C.** Effekte eines Schulsport basierten Stressmanagement Trainings auf die Stresswahrnehmung und Bewältigungskompetenzen bei Schweizer Berufsschüler-/innen , *26th Annual Conference of the German Association of Sport Sciences (DVS),* section Sport Pedagogy, University of Hamburg, Hamburg, Germany, May 30th 2013.

**Lang, C.**, Feldmeth, A. K., Brand, S., Holsboer-Trachsler, E., Pühse, U., Gerber, M. Effects of a physical education based stress management program on perceived stress and coping among adolescents attending vocational schools., *AIESEP international conference 2013*, University of Warsaw, Warsaw, Poland, July 5th 2013.

**Lang, C.** Effekte eines Schulsport basierten STressmanagement Trainings auf die Stresswahrnehmung und Bewältigungskompetenzen . *Research Colloquium, Department of Sport, Exercise and Health*, University of Basel, Basel, Switzerland, September 18th 2013.

**Lang, C.**, Feldmeth, A. K., Brand, S., Holsboer-Trachsler, E., Pühse, U., Gerber, M. Effekte eines Schulsport basierten Stressmanagements Trainings. Ergebnisse einer Längsschnittuntersuchung , *21st University-Day of the German Association of Sport Sciences (DVS),* University of Konstanz, Konstanz, Germany, September 27th 2013.

2012 **Lang, C.**, Feldmeth, A.K., Brand, S., Holsboer-Trachsler, E., Pühse, U., Gerber, M. Sportunterricht ist gut für den Schlaf. Subjektiv und objektiv erfasste körperliche Aktivität und Schlafqualität bei BerufsschülerInnen. *25th Annual Conference of the German Association of Sport Sciences (DVS),* section Sport Pedagogy, Swiss Federal Institute of Sports Magglingen, Switzerland, June 6th 2012.

Feldmeth, A.K., **Lang, C.**, Brand, S., Holsboer-Trachsler, E., Pühse, U., Gerber, M. EPHECT: Evaluation des Einflusses eines schulsportbasierten Stressmanagement-Trainings auf das psychosoziale Wohlbefinden von Jugendlichen an Berufsschulen. *25th Annual Conference of the German Association of Sport Sciences (DVS),* section Sport Pedagogy, Swiss Federal Institute of Sports Magglingen, Switzerland, June 6th 2012.

**Lang, C.** Results of the EPHECT-Study: Prevalence and correlates of self-reported and objectively assessed physical activity and sleep quality among adolescents. Is PE class good for sleep?, Research Colloquium, Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland, March 15th 2012.

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# Declaration of originality

Ich erkläre, dass ich die Dissertation

***The relationship between physical activity, sleep and coping skills among adolescent vocational students, and the effects of a physical education-based coping training.***

nur mit der darin angegebenen Hilfe verfasst und bei keiner anderen Universität und keiner anderen Fakultät der Universität Basel eingereicht habe.

Ich bin mir bewusst, dass eine unwahre Erklärung rechtliche Folgen haben kann.

Basel, den 28.09.2015 C. Lang

(Ort, Datum) (Unterschrift)