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Effects of mindfulness-based interventions on self-regulation

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Abbreviations

ACTH - Adrenocorticotropic hormone

ADHD - Attention deficit hyperactivity disorder

AUCg - Area Under the Curve with respect to ground

AUCi - Area Under the Curve with respect to increase

B-M - Body-mind program

CRH - Corticotropin-Releasing Hormone

CgA - Chromogranin A

DCCS - Dimensional Change Card Sort

EE - Ethical Enhancement

EEG - Electroencephalography

EMG - Electromyography

FA - Focused Attention

GAS - General Adaptation Syndrome

HPA axis - Hypothalamic–Pituitary–Adrenal axis

IgA - Immunoglobulin A

IMBT - Integrative Body Mind Training

MARS - Mobile App Rating Scale

M-B - Mind-body approach

MBCR - Mindfulness-Based Cancer Recovery

MBCT - Mindfulness-Based Cognitive Therapy

MBSR - Mindfulness-Based Stress Reduction

OCD - Obsessive-compulsive disorder

OM - Open Monitoring

PCOS - Polycystic Ovary Syndrome

PREP - Pass Remedial Program

PTSD - Posttraumatic stress disorder

SEL - Social and emotional learning

SEL - Social Emotional Learning

SES - socioeconomic status

SET - Supportive-Expressive group Therapy

TM - Transcendental Meditation

TSST - Trier Social Stress Test

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List of publications used in the dissertation [1]

Koncz, A., Demetrovics, Z., & Takacs, Z. K. (2021a). Meditation interventions efficiently reduce cortisol levels of at-risk samples: a meta-analysis. *Health Psychology Review*, 15(1) 56-84. https://doi.org/10.1080/17437199.2020.1760727

Koncz, A., Kassai, R., Demetrovics, Z., & Takacs, Z. K. (2022). Short mindfulness-based relaxation training has no effects on executive functions but may reduce baseline cortisol levels of boys in first-grade: A pilot study. *Children, 9*(2), 203. https://doi.org/10.3390/children9020203

Koncz, A., Köteles, F., Demetrovics, Z., & Takacs, Z. K. (2021b). Benefits of a Mindfulness-Based Intervention upon School Entry: A Pilot Study. *International Journal of Environmental Research and Public Health, 18*(23), 12630. https://doi.org/10.3390/ijerph182312630

[1] The co-authors of the listed publications have contributed to the use of the publications in my dissertation.

Preface

The idea for the topic of my doctoral study was born on the basis of the preliminary results of the then still in progress meta-analysis of one of my supervisors, Dr. Zsófia K. Takács, according to which mindfulness meditation is one of the possible interventions that can improve executive functions in childhood (Takacs & Kassai, 2019). Meditation interventions that have become the focus of our interest, and in particular, mindfulness-based programs, have proved to be an exciting research topic. In addition to the positive effects of such interventions on children’s executive functioning, it has been suggested that the potential stress-reducing effects of meditation should also be examined (Chiesa & Serretti, 2009; Sanada et al., 2016). Zelazo and Lyons (2012) proposed that one of the mechanisms for the benefits on children’s executive functions is a reduction in stress. Concerning the challenges of measuring children’s stress levels and taking advantage of my background in biology, we decided to use a biomarker of stress: cortisol hormone.

As a first step, in a meta-analysis we reviewed the available evidence in the literature regarding the efficacy of meditation interventions to reduce cortisol levels of participants. In this study, we investigated whether this stress-reducing effect is more pronounced under stressful life circumstances or in case of diseases that affect cortisol levels. The results of the meta-analysis showed that mindfulness can be particularly effective in stressful life situations. However, only a few results are available on children thus we conducted two field experiments to increase scientific knowledge in this field.

Based on the results of the meta-analysis the field experiments were conducted at a stressful time period for children: around school entry. In these studies, in addition to measuring the stress-reducing effect, we also measured the developmental effect of mindfulness on executive function skills. The first study was conducted over two summers with preschoolers right before school entry, while the second study was similar but was done with first graders right after the start of the school year.

Based on the results of this dissertation, we believe that mindfulness could be a tool for preschool and school teachers to help to improve well-being in their classrooms and to improve children's cognitive skills.

In my dissertation I follow the above-mentioned order and provide the published articles with minor changes.

1. Introduction

1.1 Self-regulatory skills

Self-regulatory skills are a set of cognitive components that are responsible for organizing and controlling our cognitive functions and behavior, to be able to achieve the set goal and if necessary, we flexibly change the plan to achieve this goal. These are top-down processes that are important for self-regulation: they enable us to adjust our behavior when an automatic action is not appropriate.

Executive function skills are the cognitive aspects of self-regulation. These skills usually considered to consist of three distinct components: inhibition, working memory and cognitive flexibility (Diamond, 2013; Diamond & Lee, 2011; Miyake et al., 2000). Inhibitory control is the ability to suppress a response that is not appropriate in a situation (Miyake et al., 2000). With poor inhibition our automatic responses dominate and thus we are guided by our entrenched habits and impulses. This skill is important because it enables us to supress stimuli that are not relevant to the situation and allows us to focus on the relevant information from the environment (this is called the inhibitory control of attention). In another case when inhibition is needed at the level of mental representations, memories or thoughts are suppressed (cognitive inhibition). For instance, inhibition is measured by the so-called Stroop task when a name of a colour is printed in another colour and participants are asked to name the colour of the print (Golden & Freshwater, 1978). In this paradigm participants have to supress to read the name of the colour, rather they should name the colour of the print. Another widely used task is the Go/No-Go paradigm (Gordon & Camarazza, 1982). Subject must respond as quickly as possible when a target stimulus appears on a computer's screen and supress the reaction if another stimulus appears.

Working memory is where information is being temporary stored, until it is processed or transferred to long-term memory. Based on the model of Baddeley and Hitch (1974) there are two subsystems of working memory that work in parallel, corresponding to two different modalities: visual and auditory. The two components are linked to the modality-independent central executive. The phonological loop can be divided into two additional subcomponents. The phonological store is responsible for dealing with phonological information such as verbal information heard or read, it is like an "inner ear". The other subcomponent is articulatory process which repeats information like an "inner voice". The visuo-spatial sketchpad plays a role in remembering visual or spatial information and is also involved in the planning of movements such as when we have to get from one place to another. The visuo-spatial sketchpad consists of two components: the visual component deals with properties such as colour or shape while the spatial component deals with the movement or location of objects. Later a fourth component, the episodic puffer was added to the model. This component makes a connection between the different subsystems of working memory and information from long-term memory and perceptual processes (Baddeley, 2010). At this point, it is important to highlight that working memory is not to be confused with short-term memory. While the latter is just for holding information temporarily in mind, working memory does not just hold, but also manipulates the information stored in the mind. Two versions of the same test are often used to measure these, for example, the digit span forward is able to measure short-term memory, while backward version is able to measure verbal working memory (Wechsler, 2003).

Shifting or cognitive flexibility is the ability to flexibly change between different rules. A switch in thinking is necessary in a new situation instead of using previously used rules of thought or belief. Another use of this skill is taking a given situation into account from several points of view, from different aspects. A classic test method for measuring shifting performance is card sorting tasks such as Wisconsin Card Sorting Task (WCST) (Berg, 1948) or Dimensional Change Card Sort (DCCS) task for children (Zelazo, 2006).

Diamond (2013) in a review summarizes that these skills play an important role in several aspects of a person's life. First in case of some mental problems such as attention deficit hyperactivity disorder (ADHD) (Diamond, 2005), depression (Tavares et al., 2007) or conduct disorder (Fairchild et al., 2009) they work worse than in the case of healthy individuals.

The most important brain region of executive functions is the prefrontal cortex (PFC) (Stuss & Benson, 1986). This region develops most rapidly in pre-school age as do the executive function skills. In case of shifting skills, a 3 year-old has difficulties switching easily between rules (for example in the Dimensional Change Card Sorting task), but by the age of 4-5 most of the children can solve it without any problem. The link between the development of shifting skills and prefrontal cortex are supported by the study of Moriguchi and Hiraki (2009) who found activation in the right and left inferior prefrontal cortex only in those few 3 year olds who had good performance in shifting but not for those who have underperformed. Similarly, in case of inhibitory control skills that measured by Stroop like tasks (e.g., Day-Night task) the development is estimated to be between 3 and 5 years (Moriguchi & Hiraki, 2013). This function is linked to right side of the frontal lobe and to the parietal areas (Mehnert et al., 2013)

Finally, the development of working memory is slower, as it lies between 4-8 years of age (Garon et al., 2008; Luciana & Nelson, 1998). Left and right lateral regions of the prefrontal cortex are active in 5-6 year old children during the use of working memory. The same has been found in adults (Tsujimoto et al., 2004) however other results show that visuospatial working memory related to the activation of the right- and verbal working memory to the left side of the prefrontal region (Tsujii et al., 2009). As seen above, the link between the development of executive functions and the frontal areas of the brain are supported by neuroimaging studies.

Self-regulatory processes play an important role in adaptive behavior, such as reducing reactive aggression (White et al., 2013). In addition, better self-regulation is associated with higher prosocial skills in children (Eisenberg et al.,1996). Children with better self-regulation skills were found to be more generous in dictator game by the age of 11 years than those with poorer self-regulation skills (Blake et al., 2015). Later, during early adolescence bidirectional relationship have been found between intentional self-regulation and prosocial behavior while between the ages 14 to 18 years, intentional self-regulation is promoted by prosocial behavior (Memmott-Elison et al., 2020). In case of aggressive behavior a negative relationship have been found between self-regulation and both proactive and reactive aggression (García-Vázquez et al., 2020) however other studies find this link only with reactive aggression (Ellis et al., 2009; Giancola et al., 1996; White et al., 2013). Based on Ellis and colleagues' (2009) results, reactive aggression stems from weaker inhibitory control.

Diamond (2013) in her review gives an overview about why executive functions are important in many areas of life An emerging number of studies show that self-regulatory skills and executive functions play an important role in school readiness and academic performance (Borella et al., 2010; Gathercole, et al., 2004), even more so than IQ (Blair & Razza, 2007). In fact, these skills are associated with mathematics and language skills. Working memory is found to be the strongest predictor of academic performance in primary education (Cortés Pascual et al., 2019). Later during adult life better productivity and greater chance of keeping a job is associated with better functioning executive function skills (Bailey, 2007Moreover, success in private life such as maintaining a well-functioning relationship (Eakin et al., 2004) and a lower likelihood to experience social problems such as emotional outbursts or crime are also related to better executive functions (Broidy et al., 2003; Denson et al., 2011).

The development level of executive functions is also highly correlated with physical and mental health. Better executive control leads to success in losing weight in adults (Crescioni et al., 2011) thus can contribute to the improved effectiveness of such weight loss programmes. Riggs and colleagues' (2010) found that primary school aged children with poorer executive functions eat more snacks. In addition to the aforementioned, the occurrence probability of diseases like asthma, cancer, high level of cholesterol and high blood pressure are also correlating with lower executive functions (Miller et al., 2011). Impairment of executive functions in certain mental disorders have been be observed. These functions are damaged in schizophrenia (Chan et al., 2004), but the condition of the patients can be improved by training executive functions (Kluwe-Schiavon et al., 2013). Executive control is also impaired in ADHD (Martel et al., 2007), obsessive compulsive disorder (OCD) (Penadés et al., 2007) or depression (Taylor-Tavares et al., 2007). Several addictions such as food addiction (Steward et al., 2018) or substance abuse (Lee & Pau, 2002) are related to lower executive functioning. Inspired by growing internet use, new research has shown that there may be a relationship between lower executive control and problematic social networking (Aydın et al., 2020).

Social factors such as being rejected by peers (Baumeister et al., 2005) or growing up as a child of divorced parents (Weaver & Schofield, 2015) are associated with lower self-regulatory capacity. Additionally, low socioeconomic status, is also a risk factor of impaired self-regulation (Blair, 2010) and higher stress levels (Cohen et al., 2006). And these stressors also contribute to the disruption of these skills (Evans & Kim, 2012).

1.2 Stress and its relation to cognitive functions

The introduction of the concept can be linked to the name of János Selye, an Austrian-Hungarian chemist, internist and endocrinologist. He proposed that the human body responds to non-specific stimuli in a non-specific way, with a general adaptation syndrome (GAS) (Selye, 1956). He distinguished 3 phases of this syndrome: alarm phase, resistance phase, and exhaustion phase. During the alarm phase, the body's energy resources and sympathetic nervous system are activated upon perceiving a stressor. During the resistance stage, the body releases additional resources, and aims to maintain normal level of physiological functions. Finally, if the stressor persists, the resistance reaches the limits of the body and resources become depleted, which finally leads to diseases. According to the definition of Lazarus and Folkman (1984), we speak of psychological stress if a person claims that a burden, constraint, or opportunity arising from his or her environment exceeds his or her personal resources. In their transactional model of stress and coping, this is a relationship between the person and the environment.

Different methods are available to assess the stress experienced by school-age children; levels of stress can be determined by observing behavior based on the report of parents or teachers or even the child's own judgment, or the monitoring of certain physiological indicators (Romer, 1993). Among physiological indicators, salivary stress proteins are popular due to their non-invasive sampling methods. These proteins are cortisol, α-amylase, chromogranin A (CgA), and immunoglobulin A (IgA) (Obayashi, 2013). Although physiological effects caused by rarely occurring short-term stress do not give rise to health risk (Stauder, 2007).

Protection from chronic stress in childhood is important because it can lead to abnormal brain development and decreased cognitive functioning (Noble et al, 2012). Elevated stress hormone (cortisol) levels or problems in cortisol regulation have been linked to not only familiar or household problems like poverty (Evans & Kim, 2003) or maltreatment (Hart et al., 1995), but in fact one study found higher baseline cortisol levels in children at childcare (Vermeer & van IJzendoorn, 2006). Stress can have a negative impact on children’s executive functions as Wagner and colleagues (2016) found: there is an inverse relationship between salivary cortisol levels, and executive function performance. Interestingly, in a meta-analysis that included results mainly from young adults Shields and colleagues (2016) found a positive effect of stress on inhibition but decreased working memory and cognitive flexibility performance. They concluded that this result supports models proposing that stress drives attention to salient information in order to either avoid or engage with the stressor. School entry is a stressful life event. Starting elementary school requires adjustment to a new environment and novel requirements in addition to building new social relationships. In fact, Groeneveld and colleagues (2013) found higher hair cortisol levels after school entry in a sample of Dutch children. With all the negative effects of stress in mind, additional efforts to support children in adaptation in this stressful life situation may be beneficial.

1.3 Cortisol and health

Self-reported assessment of stress is more prone to bias, while objective biomarkers such as cortisol levels might be more suitable for a firm test of the effects of an intervention (Matousek et al., 2010). The aforementioned cortisol is a stress hormone that is released by the activity of the hypothalamic–pituitary–adrenal (HPA) axis. As its name suggests, it creates a connection between the central nervous system and the endocrine system. In more details as a response to stress the hypothalamus starts secreting corticotropin-releasing hormone (CRH) which stimulates the pituitary gland to release the adrenocorticotropic hormone (ACTH). This hormone reaches the adrenal cortex through the bloodstream that leads to the release of cortisol into the blood. Cortisol is mostly present in blood in an inactive protein bound form. Only about 5% of the cortisol molecules circulate in the bloodstream in the biologically active form, that is without the binding protein. From the blood free cortisol is able to diffuse into the salivary glands thus into the saliva, but it can get into urine or hair as well.

In a stress-free life situation cortisol secretion shows a circadian rhythm - after an increase around waking it has a steady decrease during the day - it shows elevated concentration in reaction to stress. Acute increase of cortisol in response to physically and/or mentally challenging situations is not necessarily a reaction that should be eliminated. It simply reflects a reaction to a situation that requires adaptation. In fact, physiological stress response in the normal domain is adaptive in demanding situations (Lightman, 2008) or in changing environments (Lupien et al., 2009); under such circumstances, the lack of a stress response might be more problematic. For example, cortisol plays a role in setting the optimal arousal level. Performance of prefrontal functions (such as executive functions) improves with arousal until a certain point, but then it starts to decrease (Mayes, 2000). A similar inverted u-shaped pattern has been shown in the case of the flow experience (Csikszentmihalyi, 2000), and between sympathetic arousal and cortisol levels (Peifer et al., 2014). Consequently, optimal stress levels are important in order to maintain cognitive performance (Yerkes & Dodson 1908; Broadbent, 1965; Mendl, 1999; Sandi & Pinelo-Nava, 2007).

In case of chronic stress, cortisol shows higher concentrations after awakening (Schulz et al., 1998). However, cortisol production of the HPA-axis could become atypical, i.e., it does not necessarily imply a large increase in response to a stressful situation; rather, a blunted cortisol reactivity or prolonged increased levels without recovery can be observed (Van Ryzin et al., 2009). Higher perceived levels of stress are related to elevated daily cortisol secretion, which in turn is associated with a wide array of health complaints (Lovell et al., 2011). Chronic stress can have a negative effect on the immune and cardiovascular systems and some processes of the metabolism (McEwen, 2014). There are several mental disorders (e.g., depression or anxiety disorders) and somatic illnesses (Baričević et al., 2006; Chiodini et al., 2007) or life situations (Chida & Septoe, 2009) that are characterized by elevated cortisol levels. For instance, elevated hair cortisol levels were measured in depression (Dettenborn et al., 2012) and patients with an anxiety disorder show higher cortisol levels in hair (Steudte et al., 2011) and saliva samples (Mantella et al., 2008). Regarding somatic illnesses, type II diabetes is associated with elevated blood serum cortisol (Chiodini et al., 2007), while Tsilchorozidou and colleagues (2003) showed higher daily cortisol production from urine cortisol metabolites in polycystic ovarium syndrome (PCOS) patients. It is known that stressful life situations (e.g., low socioeconomic status, school entry) are associated higher salivary cortisol levels (Cohen et al., 2006, Groeneveld et al., 2013). Thus, taking into consideration the health risks of and the number of conditions that are linked to elevated cortisol levels, investigating the efficacy of interventions that might help reducing elevated cortisol levels is of high importance. Furthermore, it is important to assess whether benefits are sustained over time (Slopen et al., 2014).

Cortisol levels elevate not only in case of chronic but also acute stress temporary. This elevation is highest in social-evaluative and uncontrollable situations such as the Trier Social Stress Test (Dickerson & Kemeny, 2004). Stress reactivity is also assessed with children with an adopted version of the Trier Social Stress test (Buske-Kirschbaum et al., 1997).

Results regarding sex differences in baseline cortisol levels are mixed. Kirschbaum and colleagues (1992) failed to find any effect of gender on baseline salivary cortisol levels in three studies. In contrast, Larsson and colleagues (2009) showed higher morning baseline blood cortisol levels in women, while Roelfsema and colleagues (2017) found lower total daily blood cortisol production in premenopausal women compared to men.

There is no clear evidence for a gender difference in stress reactivity in healthy children (Allen et al., 2017). However, Mazurka and colleagues (2017) found among depressed adolescents that boys show higher cortisol reactivity than girls. In case of adults, women were found to produce less cortisol in reaction to stress (Reschke-Hernández et al., 2017; Kudielka & Kirschbaum, 2005).

1.4 Fostering executive function skills

For fostering children's executive functions several possibilities have been proposed such as computer programs, curricula, yoga, mindfulness meditation and sports (Diamond & Lee, 2011). In a meta-analysis Takacs and Kassai (2019) collected what kind of interventions are used to improve executive functions and tested their effectiveness. Computerized trainings are focusing on directly practicing cognitive skills. The most researched program is CogMed, that is designed to improve working memory and also successfully develops mathematical skills (Holmes et al., 2009). There are other tools used in fewer studies also aiming to improve working memory, these are Memory Booster (St. Clair-Thompson & Holmes, 2008; St. Clair-Thompson et al., 2010) and Jungle Memory™ (Alloway et al., 2013; Nelwan & Kroesbergen, 2016) programs. Braingame Brian (Prins et al., 2013), Mate Marote (Lopez-Rosenfeld et al.,

2013) and LocuTour Multimedia Cognitive Rehabilitation (Lomas, 2001) are aimed to improve all three components of executive functions.

There are noncomputerized games and trainings for children that are also explicitly trains executive functions and are able to improve these skills. For example, in the study of Tominey and McClelland (2011) children must start or stop an activity when they see a signal to do so as a training of the inhibitory control. In other studies, the components of the executive functions are trained with tasks which are similar to the tests used to measure these skills (e.g., Caviola et al., 2009; Traverso et al., 2015).

Physical activity can also have a positive impact on executive functions. Aerobic exercises for example running, cycling or rope jump and more complex aerobic programs e.g., FitKids (Hillman et al., 2014) are found to be less effective than cognitively engaging exercises like table tennis, ball games or martial arts (Diamond & Ling, 2016; Takacs & Kassai, 2019). Art activities like learning to drumming, keyboard or voice (Schellenberg, 2004) or interventions based on drama (Smith, 2010) and pretend play have been found noneffective (Thibodeau et al., 2016)

There are complex full-time curricula which may be suitable for develop executive functions. They have the great advantage of integrating exercises into the children's daily activities and tasks that are designed to develop executive function skills (Diamond & Lee, 2011) however Takacs and Kassai (2019) found only marginally significant small effect of these programs. Montessori is an alternative education method with multi age-classrooms where cooperation and the development of social skills are given a high priority and there is no grading. (Lillard & Else-Quest, 2006). The Tools of the Mind curriculum (Bodrova & Leong, 1996, 2007) build's on Vygotsky's approach according to which the cognitive self-regulation and social-emotional self-regulation are not separate domains, so the programme also has a strong emphasis on developing social skills besides cognitive skills. The Program for Self-regulation and Executive Functions (PIAFEx) (Dias & Seabra, 2013) is built up on activities which require the use of executive functions and teaches children how these skills can help to better organise their behavior.

Teaching new techniques that contribute to better self-regulation found to be effective in improving executive function skills. (Takacs & Kassai, 2019). These can be strategy teaching interventions, biofeedback-induced relaxation programs or mindfulness interventions. Strategy teaching intervention programmes such as Head Start REDI (Bierman et al., 2007), Preschool

PATHS (Domitrovich et al., 2007), Pass Remedial Program (PREP) (Deaño et al., 2015) are not part of the children's curriculum, but are used as extra-curricular activities. During biofeedback-enhanced relaxation tasks researchers use electroencephalography (EEG) (Beauregard & Lévesque, 2006; Parziale, 1982) or electromyography (EMG) measurements to provide feedback to the participant that the relaxation task is being performed correctly (Omizo & Michael, 1982; Rivera & Omizo, 1980).

Finally, in their meta-analysis Takacs and Kassai (2019) found mindfulness-based interventions to be an effective intervention for children for enhancing executive functions like working memory and inhibition skills however, they highlight the number of studies was still quite limited. These programs are the Kindness Curriculum (Flook et al., 2015), Master Mind (Parker et al., 2014) and programs based on Mindfulness-based stress reduction. (for more details about mindfulness-based approaches please see Chapter 1.7) Additionally, Moore and Malinowski (2009) found higher performance on a cognitive flexibility test among adult meditators.

1.5 Categorisation of meditative interventions

Some authors attempt to categorise meditative interventions. Dahl and colleagues (2015) mention three main categories. In the attentional family the exercises train processes that play a role in attention regulation (e.g., the mindfulness component of the Mindfulness Based Stress Reduction (MBSR) and the Mindfulness Based Cognitive Therapy (MBCT)). The constructive family involves programmes that aim to strengthen psychological processes that contribute to well-being. These programs seek to change thoughts and emotions by improving patience, calmness and prosocial skills. This category includes, for example, the Loving-Kindness meditation. The deconstructive family aims to eliminate maladaptive thinking processes (e.g., the cognitive components of the MBCT).

In another categorisation system five categories of meditation techniques are mentioned by Simkin and Black (2014). During focused attention trainings (FA) meditators are concentrating on explicit objects to avoid the mind wander. The widely used mindfulness-based programs like Mindfulness Based Stress Reduction (MBSR) and Mindfulness Based Cognitive Therapy (MBCT) belong here. The aim of open monitoring (OM) techniques is not to concentrating on explicit objects, rather the practitioner is trying to be a monitoring state. Meditative techniques in this category are Sahaja type meditations. The third category is transcendental meditation (TM). In this technique, instead of focusing on something or being aware of the moment, the meditator repeats a mantra. The goal this action to subsiding thoughts and mental processes.

Mind-body approaches (M-B) can involve components from the previous three techniques. And finally, body-mind programs (B-M) use movement series thus these are body centered but can also incorporate elements from the first three types. Body-mind programs include movements like dance therapy or yoga etc.

In a third system described by Vago and Silsbersweig (2012) focused attention (FA) and open monitoring (OM) practices are similar to Simkin and Black's (2014) categories, while Ethical enhancement (EE) practices overlap with Dahl and colleagues' (2015) Constructive category.

1.6 Mindfulness-based programs

Interest in mindfulness has been growing in recent years and it is used in many areas such as stress reduction (Oken et al., 2010), performance and productivity enhancement at work (Hyland et al., 2015; Kersemaekers et al., 2018), the development of cognitive skills such as executive functions (Diamond & Lee, 2011) or the reduction of the symptoms of certain disorders such as ADHD (Chimiklis et al., 2018) or autism (Semple, 2018). Mindfulness is derived from Buddhist philosophy and one of the most widespread approaches among different meditative approaches. The concept of mindfulness is to be in the present moment without judgment (Kabat-Zinn & Hanh, 2009). Mindfulness meditation uses different objects to drive the meditator's attention to the experiences of the present moment including observation of one's breathing, bodily sensations, thoughts and emotions and the environment (e.g., sounds). During mindfulness meditation meditators are required to monitor their attention and bring it back to the object of the meditation if their minds wander. When an individual is in this open and conscious state, it is called the state mindfulness, that can be measured by the Toronto Mindfulness Scale (Lau et al., 2006). It is important to note that mindfulness in general is seen as an approach which is present in all areas of life instead of just an exercise that is practiced for a few hours a week. The tendency of an individual to be in the present moment in his or her daily life is called trait mindfulness (Baer et al., 2006).

Meditation is often used in combination with other practices. For instance, Integrative Body Mind Training (IMBT) uses mindfulness training elements and also body relaxation and mental imagery (Tang, 2011). Mindfulness-Based Stress Reduction (MBSR) and Mindfulness-Based Cognitive Therapy (MBCT) combine mindfulness meditation practices with elements of cognitive behavioral therapy or some other psychoeducational elements (Fjorback et al., 2011). The most commonly used components in mindfulness-based programs are breath awareness, psycho-education and group discussions (Zenner et al., 2014).

Shapiro and colleagues (2006) propose three core elements (axioms) of mindfulness: intention, attention and attitude. All three components occur simultaneously. Intention means the purpose for which a person performs these exercises. Shapiro (1992) proposes that intentions of practicing are self-regulation, self-exploration and, as an end of the process, self-liberation. Attention is the ability of the individual to control his or her attention thereby focusing on himself or herself, thus on his or her external or internal experiences. At this point Shapiro mentions that three aspects of attention such as sustained attention (focusing on something for a long period of time), switching (changing the focus of our attention between different things like mental sets or objects) and cognitive inhibition ("secondary elaborative processing of thoughts, feelings and sensations" (Shapiro et al., 2006, p. 376)) would be enhanced. Attitude is the third core component which means the practitioner exercises his or her attention with an open and accepting attitude without judgment.

In the last 10 years, the number of studies that observed the effects of mindfulness programs developed for children still lags behind the number of studies carried out with adults (Butterfield et al., 2020). Butterfield and colleagues (2020) found 87 studies that tested mindfulness interventions among children, 65 of them were controlled and 18 applied an active control group. Randomisation was applied in only about half of them (48) and 43 were held in schools. Takacs and Kassai (2019) in a meta-analysis that included studies aimed to improve executive function skills among children up to 12 years, found only six studies that tested mindfulness.

For children, mindfulness programs used in educational settings are more prevalent such as Kindness Curriculum (Flook et al., 2015), MindUP (The Hawn Foundation, 2011) or Learning to BREATHE (Broderick & Frank, 2014). Feasibility and acceptability of mindfulness interventions among school age children have been shown, they are generally open and willing to participate and to be able to understand and apply mindfulness strategies (Burke, 2010).

The Kindness Curriculum was developed by the Center for Healthy Minds at the University of Wisconsin–Madison for pre-schoolers. The program is 12-week-long, it is held twice a week and consists of 30-minute sessions. The program incorporates children's literature (stories), songs and some kinds of movement exercises. Also, it addresses topics such as forgiveness, gratitude, and teaches about emotions. On the webpage of this program, there are some free downloadable activities for five age groups from 1 year olds to 12 year olds. (https://www.thekindnesscurriculum.com). The MindUP program is a mindfulness-based learning (SEL) curriculum for school-aged children that aims to develop social and emotional competencies like relationship skills or self-awareness. In each session children practice mindfulness and can learn about the effects of thoughts' and feelings' and their effects on behavior. Additionally, the program encourages participants to be altruistic. The program consists of 15 lessons (Maloney et al., 2016). The Learning to BREATHE is originally a program for adolescents but there is a modified version available for college students. The program has 6, 12, and 18 session versions. The aim is to improve emotion regulation, gratitude and compassion. Also, it teaches new stress management techniques and intended to encourage participants to incorporate mindfulness elements into their daily life.

Besides face-to-face application of mindfulness programs, technology assisted mindfulness is more and more popular. This approach was found to be feasible and enjoyable for school aged children as well (Tunney et al., 2016). Thanks to the widespread use of smartphones, which are used for numerous things aside from making calls and texting, such as gaming and listening to music, more and more applications are appearing and meditation software are no exceptions. In a review Nunes and colleagues (2020) found 57 mindfulness-based apps that are appropriate for children, based on the Android or iOS app store's description. Most of the applications do not achieve acceptable quality on the Mobile App Rating Scale (MARS). Although, most of the apps are free, hence easily accessible to everyone, only two applications are evidence based. Fortunately, the aforementioned two apps, Headspace: Meditation and Mindfulness and Smiling Mind, are free. The content in Headspace which is available for free is a 10-day long introduction program that incorporates breathing meditation, body scan, sitting meditation and content about thinking without judgment. Smiling Mind also contains many hours of meditation for all ages for free.

1.7 Effects of meditation on stress and anxiety

In a previous meta-analysis Goyal and colleagues (2014) found that mindfulness mediation has moderate beneficial effects on symptoms of anxiety (d = 0.38) and depression (d = 0.30), but no convincing evidence on stress in clinical populations. In a meta-analysis MBSR compared to wait-list controls was found to be effective in reducing self-reported stress (Cohen's d for MBSR group was 0.74, while it was -0.21 for the control group), however, results are not conclusive whether these benefits remain more than 3 months later (Chiesa & Serretti, 2009). In a systematic review, Fjorback and colleagues (2011) found that only the minority of the studies include follow-up assessment after more than a year. Sanada and colleagues (2016) conducted a meta-analysis of the available randomized controlled trials (RCTs) of mindfulness-based programs on salivary cortisol levels in non-clinical adult populations and revealed a significant, moderate-sized benefit of almost half a standard deviation (g = .41, p = .025).

Pascoe and colleagues (2017) synthesized the results of the RCTs regarding the effects of any types of meditation compared to an active control group on blood cortisol data and also found a significant, medium effect (Z = -2.92, p < .01). However, there is a call for investigating the long-term effects of meditation (Chiesa & Serretti, 2009; Fjorback et al., 2011).

A mindfulness program called MindfulKids was found effective in preventing stress and behavioral problems in primary school students (Weijer-Bergsma et al., 2012). In the same vein, a meta-analysis by Kallapiran and colleagues (2015) found that mindfulness-based interventions reduce the symptoms of stress and anxiety in children and adolescents. Regarding results on children's cortisol levels, Sibinga and colleagues (2013) tested the effects of a 12-session-long mindfulness-based stress reduction (MBSR) program compared to a health education program among seventh- and eighth-grader boys from low-income families. Results show that participants of the MBSR program benefited: their cortisol levels increased to a lesser extent than that of the control group. In contrast, Schonert-Reichl and colleagues (2015) tested the effect of a mindfulness-based social emotional learning (SEL) program among fourth- and fifth-graders and found that morning cortisol levels were higher on post- but not on pre-tests in those children who attended the 12-lesson-long SEL program compared to those who participated in a social responsibility program.

The effects of mindfulness on cortisol reactivity is controversial, however, Brown et al. (2012) found that trait mindfulness is associated with lower cortisol reactivity to a Trier Social Stress Test (TSST) among adults. On the other hand, a short (3-session-long) mindfulness program was found to increase salivary cortisol reaction compared to a cognitive training program (Creswell et al., 2014).

1.8 Effects of meditation on children's behavior

In line with the positive effects of mindfulness programs on children's self-regulatory skills, such an intervention could also reduce children's behavior problems. For instance, if mindfulness practice improves executive functions, especially inhibitory control, it could potentially decrease children's aggressive behaviors because lower inhibitory control is associated with higher aggression (O'Toole et al., 2017). Finally, mindfulness practice can nurture children's prosocial skills. In a review Cheang and colleagues (2019) reviewed the scientific literature and found that mindfulness-based interventions may have positive effects on children's empathy and compassion. However, it should be noted that mindfulness programs developed for children often have content that directly targets prosocial skills such as kindness practice.

1.9 Theories on how mindfulness works

According to Creswell and Lindsay (2014) mindfulness has positive effects on health outcomes via improving stress management (mindfulness stress buffering hypothesis). The authors proposed that mindfulness affects both top-down and bottom-up stress processes in the brain including increased activation in regulatory areas like the prefrontal cortex and decreased stress reactivity in, for instance, the amygdala. Based on the stress buffering account, Creswell and Lindsay (2014) predicted that mindfulness-based interventions should have the largest effect on at-risk populations: highly stressed people or populations with diseases that are susceptible to stress such as mental disorders and somatic illnesses like inflammatory diseases or diabetes.

Zelazo and Lyons (2012) proposed that mindfulness programs contribute to the development of the executive function skills in two ways. First, mindfulness practice trains self-regulation by practicing monitoring and consciously driving one’s attention to the object of the meditation (top-down processes). Second, such practice reduces stress, which in turn facilitates cognitive performance (bottom-up processes).

Based on these two theories mindfulness might affect on executive function skills through reducing stress and can be especially effective for people who are in a stressful life situation.

2. Objectives

Based on the above, my aim in my doctoral work was to examine whether meditation really reduces stress and if so, which groups are most effective for. I would also like to test whether practicing meditation has an impact on the development of self-regulation through stress reduction because stress can be seen as a bottom-up process (Zelazo & Lyons, 2012). For this we aimed to summarize all available results of randomised controlled trials regarding the effect of meditation on cortisol levels. In the analyses, we wanted to examine what factors (e.g., risk status of the participant for elevated cortisol levels, age, length of the intervention etc.) influence the effectiveness of these interventions.

Following the meta-analysis, my goal was to extend the very limited number of results on mindfulness programs available for children. For this we take into account the mindfulness stress buffering hypothesis of Creswell and Lindsay (2014) that say higher effect can be expected among at-risk populations. As school entry is regarded as a stress factor for children, first in a randomized controlled trial right before school entry we aimed to test whether a short intensive mindfulness training is able to foster executive function skills and reduce the stress caused by starting school.

Second in a modified version of the previous field experiment we tested whether a slightly longer and different timing intervention could be more effective for children who just started the first grade.

3. Study 1:

Meditation interventions efficiently reduce cortisol levels of at-risk samples: A meta-analysis

3.1 Aim of the study

The main aim of the present study was to assess whether meditation is more effective in samples who are in most need of stress reduction: samples with elevated cortisol levels, that is, clinical samples and participants in stressful life situations as compared to healthy subjects with supposedly lower cortisol levels. Secondly, we investigated whether benefits of meditation are sustained over time by focusing on the latest follow-up assessments. Additionally, we extended the previous results in several ways: (i) we included all kinds of meditative interventions as we expected similar benefits of mindfulness-based as other schools of meditation such as zen or transcendental meditation, (ii) we also included any cortisol sampling procedure, not only saliva or blood, but also urine samples because there is a high correlation between cortisol concentration measured from blood and saliva samples (Obayashi, 2013), and urine (Contreras et al., 1986). Besides the aforementioned, hair cortisol is also included because it reflects the changes in cortisol secretion as well (Wright et al., 2015), (iii) we did not restrict our search to active control conditions, and finally, (iv) we did not restrict our search according to participants' age or clinical status as we aimed to test whether meditative interventions have different efficacy at different ages and in samples who are at risk for elevated cortisol levels.

3.2 Hypotheses

H1: Previous meta-analyses found that meditative interventions able to decrease cortisol levels (Pascoe et al., 2017; Sanada et al., 2016). However, while Goyal and colleagues (2014) found an effect of mindfulness-based programs (e.g., MBSR, MBCT, Zen meditation etc.), they did not find one of mantra meditation (e.g., Transcendental meditation). The evidence in the included studies regarding mantra meditation was low or insufficient. On the other hand, in a literature review Walton and colleagues (2002) states that transcendental meditation does reduce stress. In line with previous results (Pascoe et al., 2017; Sanada et al., 2016), it was hypothesized that meditation interventions decrease cortisol levels because of their stress reducing effects (Goyal et al., 2014).

H2: We expected a larger effect for samples that are at risk for elevated cortisol levels (based on the mindfulness stress buffering account of Creswell and Lindsay (2014).

H3: Regarding the long-term effects of these programs, we expected smaller effects with more and more time after the end of the intervention. For instance, Hsiao and colleagues (2016) found a larger effect right after the intervention as compared to follow-up measures at 3, 6 and 12 months.

3.3 Methods

3.3.1 Operational definitions

Meditation in the present study was defined as a contemplative activity during which subjects focus their attention on the object of the meditation instead of letting their minds wonder, regardless of what the object of meditation is: for instance, breathing, sensations in the body, a mantra, sounds or one's thoughts. Accordingly, all schools of meditative practices (e.g., mindfulness, transcendental or zen meditation) were included (similar to Goyal et al., 2014; Pascoe et al., 2017).

We aimed to assess the effect specifically for subjects who are at a risk for elevated cortisol levels. In the primary studies the effect of meditation was assessed regarding a variety of at-risk samples, for example, participants with a somatic illness (e.g., cancer (Bränström et al., 2013), polycystic ovary syndrome (Stefanaki et al., 2015), cardiovascular disease (Robert McComb et al., 2004), type 2 diabetes (Jung et al., 2015)), or samples with a mental illness (e.g., depression (Gex-Fabry et al., 2012), or post-traumatic stress disorder (Kim et al., 2013)) in addition to clinically indicated samples such as participants showing depressive symptoms (Prakhinkit et al., 2014). Furthermore, participants living in stressful life circumstances were also considered as at-risk groups (e.g., cancer survivors (Carlson et al., 2013), dementia caregivers (Oken et al., 2010), or low socioeconomic status (Sibinga et al., 2013)). See Table 1. for an overview of the risk factors in the primary studies in addition to references confirming that these conditions are associated with elevated cortisol levels.

Table 1.

Risk factors for elevated cortisol levels in the primary studies

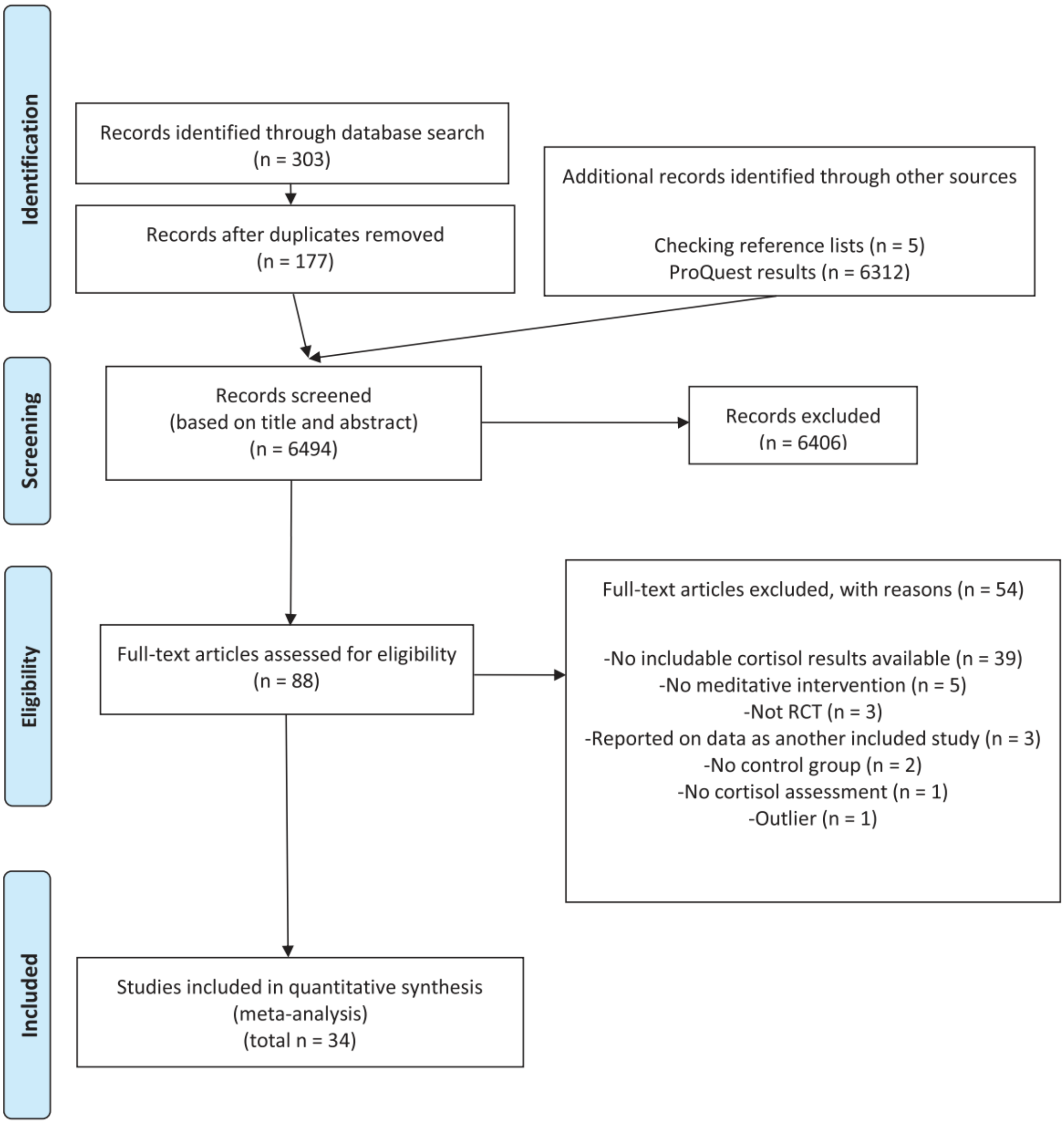
Risk factor	Reference
Cancer diagnosis	Andersen et al., 1989
Chronic pain (e.g.: fibromyalgia)	Van Uum et al., 2008
Depression	Dettenborn et al., 2012
Generalized anxiety disorder	Mantella et al., 2008
Glaucoma	Schwartz et al., 1987
History of cardiovascular disease	Manenschijn et al., 2013
Inflammatory gastrointestinal diseases (e.g.: colitis ulcerosa, Cohn's disease)	Baričević et al., 2006
Low socioeconomic status (Low-SES)	Cohen et al., 2006
Polycystic ovary syndrome (PCOS)	Tsilchorozidou et al., 2003
Posttraumatic stress disorder (PTSD)	Steudte et al., 2011
Stressful life situations (Caregiving of patients with dementia can lead to depression over time Wright et al., 1999)	Chida & Steptoe, 2009
Type 2 diabetes	Chiodini et al., 2007

3.3.2 Search strategy

We conducted a systematic search in the databases of Web of Science (Core collection), EBSCO (PsychInfo, PsychArticles, MEDLINE) and PubMed for journal articles and in the ProQuest database for dissertations and theses with a detailed search string (Appendix 1) up to November 15, 2018 to locate all randomized controlled trials that used meditation as an intervention and cortisol measures before and after the intervention to calculate the change in cortisol levels as an outcome (see the PRISMA diagram in Figure 1). All searching and screening procedures were done independently by the first author and a research assistant. As a secondary search, the reference lists of the included articles and other review studies were checked to find all relevant articles by the coders of the study.

Figure 1.

PRISMA Flow diagram



3.3.3 Inclusion criteria

(1) The intervention condition had to include meditation as the main component of the intervention (e.g., the intervention was a meditation-based program (like MBSR or MBCR). The study was excluded if meditation was only a small part of the program (e.g., Dialectical Behavior Therapy is a type of cognitive-behavioral program for treating mental disorders that also uses mindfulness elements during acceptance procedures (Dimeff & Linehan, 2001), however, the basis of the program is not mindfulness).

(2) There had to be a passive or an active control condition without meditation to which the meditation condition could be contrasted.

(3) The study had to have a randomized controlled design.

(4) There had to be an outcome measure regarding participants' cortisol levels on pre- and post-test/follow-up: either a single measure, the average of multiple measure(s), the diurnal mean or the area under curve respect to the ground (AUCg) during the day. Alternatively, the first sample taken before a stress test was also included as long as it was taken at approximately the same time of the day on the post-test/follow-up as on the pre-test.

(5) The study had to be written in English.

We had no restrictions regarding the age or clinical status of the participants in the primary studies.

3.3.4 Coding procedure

The following information were coded: (a) bibliographic information, (b) sample characteristics (e.g., at-risk for elevated cortisol levels or not), (c) characteristics of the meditation intervention (e.g., length of the intervention), (d) characteristics of the control condition (e.g., active or passive), (e) cortisol sampling, and (f) effect size information (sample sizes, and means and standard deviations of cortisol measures in the meditation and the control groups on pre- and post-test/follow-up), (g) the number of days between the end of the intervention and the post-test/follow-up cortisol sampling, (h) type of meditation, (i) intervention components, (j) risk of bias. If the necessary information to calculate the effect size (for example, if a study reported only diurnal slope but not the means of cortisol levels at each time point (e.g., Bränström et al., 2013)) or to estimate the number of days between the end of the intervention and the cortisol sampling was not available, we contacted the authors by e-mail.

In order to test the long-term effects of meditation intervention programs, we conducted a meta-regression analysis in which we used the elapsed time after the intervention until the cortisol measurement to test whether the effects of the interventions fade with time. In case of hair samples (because it is a retrospective analysis with about one cm of hair sample reflecting the total cortisol production from the last month) we calculated the 'mean' of the sampling time (for example in case of a hair sample from one month after the intervention we used 15 days). If the hair sample was collected within one month from the end of the program (e.g., Nery et al., 2018; Younge et al., 2015) we excluded the study because the sample thus contained cortisol from the time of the intervention and cannot be regarded as a post-test.

To test the effect of the length of the intervention we coded the whole length, but we made an exception for one study (Vandana et al., 2011) in which subjects partook in an eight-month-long intervention. Measures were taken after 48 hours, two months and eight months from the start of the program. In this case instead of using the measure taken at the end of the intervention (after 8 months), we chose to include the intermittent measure taken two months after the beginning of the intervention because two months of intervention was more similar in length to the interventions used in the other studies.

Additionally, we coded risk of bias in the included randomized controlled trials using the Cochrane Collaboration's risk of bias tool 2.0 (Sterne et al., 2019). This criteria tool measures with specific questions on five domains such as the randomization process, assignment to intervention, missingness of data, the measurement and selective reporting. Based on the five domains' results, coders decide the overall risk level of the study.

All included studies were coded by two independent coders. The coders were the first author, the research assistant who was involved in the searching and screening process along with other university students. Disagreements were settled in discussion, and if the coders could not make a decision, the first and the last authors were included in the discussion. The Krippendorff's alpha values of inter-rater reliability (Krippendorff, 1980) were calculated with the KALPHA macro for SPSS (Hayes & Krippendorff, 2007). Based on these values inter-rater reliability was always acceptable, ranging from 0.99 (total time of the intervention) to 1.00 (gender distribution).

3.3.5 Meta-analytic procedure

In this meta-analysis we synthetized the evidence regarding the effects of meditation on change in cortisol levels from pre-test to post-test/follow-up assessment. Additionally, we used a meta-regression analysis to test the effect of time between the end of the intervention and the cortisol assessment to investigate whether effects fade with time. The dependent variable in the present study was the standardized mean difference between the meditation and the control group in the change in cortisol from pre- to post-test/follow-up. We utilized the standardized mean difference as an effect size because different sampling strategies were used in the primary studies: a single measurement (Jung et al., 2015), the diurnal mean calculated from more measures (Cash et al., 2014) or the area under the curve respect to the ground (AUCg). If different cortisol indices were reported in a study, we preferred the AUCg measure first, followed by the mean of multiple measures instead of a single measurement. We used the effect size estimate Hedges' g, which is similar to Cohen's d but corrects for small sample sizes (Borenstein et al., 2009). Effect sizes are considered low around 0.20, medium around 0.50 and large around 0.80 (Cohen, 1988) as an agreement in behavioral sciences (Stoové & Andersen, 2003). Only one study (Malarkey et al., 2013) reported the correlation between the pre- and post-test scores so we standardized the effect sizes by the post-test standard deviations. Data was entered and analysed in the Comprehensive Meta-Analysis Software 3.3 (Borenstein et al., 2014). If more post-test/follow-up measurements were available in a study, we included all of those and the program calculated the mean of the effect sizes before including the study in the grand average over the different studies. However, for testing the sustained effects in a meta-regression, we only included the results of the cortisol sample that was taken the latest from the end of the intervention program. In case results were reported for more than one control condition in a study we included both contrasts. For instance, Prakhinkit et al. (2014) used a sedentary control and a traditional walking exercise as control conditions. Again, the software takes the average of the two effect sizes in one study as these are not independent from each other before calculating a grand average.

A positive effect size indicates the advantage of the meditation intervention for cortisol levels as compared to the control condition, that is, either a larger decrease or a smaller increase from pre- to post-test. Effect sizes were inspected for outliers (exceeding a standardized residual of +/-3.29). As the primary studies employed different samples, meditation interventions, control conditions and cortisol sampling approaches, average effect sizes and corresponding 95% confidence intervals were calculated based on the random effects model, which allows for between-study variances (Borenstein et al., 2009).

Publication bias means that due to having more difficulty publishing non-significant results, significant findings might be overrepresented in meta-analyses (Borenstein et al., 2009). We used the funnel plot method (Egger et al., 1997) to assess the possibility of publication bias, which plots the inverse of the standard errors (precision) against the effect sizes of the individual studies. An asymmetrical plot suggests that studies with non-significant results might be missing. In case of asymmetry, Duval and Tweedie's trim and fill method (Duval & Tweedie, 2000) can be applied to adjust the average effect size. Rosenthal's fail-safe N method (Rosenthal, 1979) estimates he confidence of the results by calculating the number of studies with non-significant results that would be needed to turn the average effect non-significant. As a rule of thumb, the average effect size is robust if the number is larger than 5k +10 (where k is the number of the studies included). Additionally, we used the weight function model (Vevea & Hedges, 1995) that gives a corrected effect size as a result of the adjusted model. This adjusted estimate corrects the effect with pre specified weights of p-value intervals. Heterogeneity of the average effect size was calculated by the Q-statistics and I2. Significant heterogeneity means that the variability between effect sizes cannot be attributed to sampling error alone (Borenstein et al., 2009). When the Q-value shows a heterogenous effect it is sensible to conduct moderator analyses in order to explain the variance. The I2 (Higgins & Thompson 2002) shows what part of the total variation is caused by the heterogeneity between studies in percentage. As a rule of thumb of interpreting I2 values under 40% is considered low, between 40-60% moderate, and 60-90% substantial (Schünemann, 2013). Moderator analyses were conducted to 1. test the difference between at-risk and no-risk samples, 2. test the effects of time (the number of days between the end of the intervention and the cortisol sampling on post-test/follow-up), and 3. to check potential sources of bias such as differences in the interventions, the control conditions and the cortisol sampling procedure. In case of categorical variables, we applied subgroup analyses, while for numerical variables regression analyses were conducted. Statistical power calculations were based on recommendations of Hedges and Pigott (2004). If there was not sufficient statistical power, only descriptive results were reported regarding the moderator variables (see Kassai et al., 2019 for a similar procedure). For more details on the statistical power analyses see Appendix 2. Each of the above-mentioned analyses were performed separately for each sample source.

3.4 Results

3.4.1 Effect of meditation on blood cortisol

We synthetized the results of 10 studies including data of 395 participants' using blood samples. For the characteristics of the studies see Table 2. Four of these studies utilized a focused attention (FA) type meditation program and were based on mindfulness, three of them used transcendental meditation, two applied body-mind and one mind-body program. In all the studies one blood sample was taken. Only one study did not provide more information (Jung et al., 2015), while nine studies (90%) sampled cortisol in the morning. Five mentioned that sampling was done after fasting. The classic fail-safe N method showed that 67 non-significant studies would turn the average effect non-significant. Thus, according to Rosenthal's criterion, the average effect was robust. The funnel plot was symmetrical so there were no signs of a publication bias. Risk of bias in the included studies was 'some concerns' in case of eight studies, while in case of one study it was low and in an other it was high (see Table 2). Meditation interventions had a medium effect on the change in cortisol levels (g = 0.62, k = 10, SE = 0.21, 95% CI = [0.22, 1.02], p = .003). The effect was heterogeneous (Q (9) = 28.99, p = .001), I^2= 68.95, 95% CI = [0, 92]. The weight function model produced a bigger effect estimate (g = 1.20, 95% CI = [0.47, 1.91]) and the likelihood of this model was -1.66 and for the original model it was 0.70. The likelihood ratio test was significant (p = .03) indicating that the adjusted model could be better. Additionally, we tested the overall effect excluding the one study at a high risk for bias (Robert-McComb et al., 2004). The effect remained medium-sized and significant (g = 0.62, k = 9, SE = 0.23, 95% CI = [0.18, 1.07], p = .006). This effect was also heterogeneous (Q (7) = 28.98, p < .001), I^2= 72.40, 95% CI = [3, 94].

There was also a significant medium-sized effect for at-risk samples and a large but non-significant effect for no-risk samples. Without the high-risk bias study, there was a similar, marginally significant effect for at-risk samples (g = 0.50, k = 7, SE = 0.26, 95% CI = [-0.004, 1.007], p = .052) and it was heterogeneous (Q (6) = 21.06, p = .002), I^2= 71.51, 95% CI = [0, 93].

Table 2.

Characteristics of the studies included in the meta-analysis

Study name	Participants (age in years and gender distribution if available)	Risk for elevated cortisol levels	Intervention, (sample size), (type of meditation)	Control condition (sample size)	Total intervention time	Cortisol measurements	Time from the end of the intervention until cortisol sampling	Risk of bias
Bergen-Cico et al., 2014	age: *M* = 48, *SD* = 16, range: no data; gender: 90% male	Risk (diagnosed: PTSD)	Primary Care brief Mindfulness Program (PCbMP); (*n* = 9), (FA / MBI)	Passive: Primary Care Treatment as Usual (PC-TAU); (*n* = 21)	6 hours (4 sessions through 4 weeks)	Five saliva samples each day at specified times for 2 consecutive days (AUCg)	-	Some concerns
Bowden et al., 2012	age: *M* = 34, range: 18-50; gender: 36% male	No risk	Mindfulness procedure; (*n* = 12), (FA / MBI)	Active: Brain Wave Vibration (BWV); (*n* = 12)	12.5 hours (10 through 5 weeks)	Two saliva samples between 11 a.m. and 3 p.m.	-	Some concerns
Bowden et al., 2012	age: M = 34, range: 18-50; gender: 36% male	No risk	Mindfulness procedure; (*n* = 12), (FA / MBI)	Active: Iyengar Yoga; (*n* = 9)	12.5 hours (10 through 5 weeks)	Two saliva samples between 11 a.m. and 3 p.m.	-	Some concerns
Bränström et al., 2013	age: *M* = 51.80, *SD* = 9.86; range: no data; gender: 1% male	Risk (diagnosed: cancer)	Mindfulness Based Stress Reduction (MBSR); ($n_{3\ month}$ = 29, $n_{(6\ month)}$ = 30), (FA / MBI)	Passive: Wait-List Control; ($n_{(3\ month)}$ = 37, $n_{(6\ month)}$ = 38)	16 hours (8 sessions through 8 weeks)	One saliva sample immediately after awakening (a.m.)	Sampling after 3 and 6 months (90 and 180 days)	Some concerns
Carlson et al., 2013	age: *M* = 54.66, *SD* = 9.71 (intervention), *M* = 53.62, *SD* = 10.11 (control); range: no data; gender: 0% male	Risk (distressed and diagnosed: breast cancer survivor (stage I - III))	Mindfulness-based cancer recovery (MBCR); (*n* = 66), (FA / MBI)	Active: Supportive-expressive group therapy (SET); (*n* = 68)	18 hours (8 sessions through 8 weeks + one 6-hour workshop)	Four saliva samples at awakening, noon, 5 p.m., and bedtime through 3 days to calculate diurnal mean	Sampling within two weeks after the intervention (14 days)	Low
Carlson et al., 2013	age: *M* = 54.66, *SD* = 9.71 (intervention), *M* = 56.27, *SD*= 1.89 (control); range: no data; gender: 0% male	Risk (distressed and diagnosed: breast cancer survivor (stage I - III))	Mindfulness-based cancer recovery (MBCR); (*n* = 66), (FA / MBI)	Active: 1-day stress management seminar (SMS); (*n* = 34)	18 hours (8 sessions through 8 weeks + one 6-hour workshop)	Four saliva samples at awakening, noon, 5 pm, and bedtime through 3 days to calculate diurnal mean	Sampling within two weeks after the intervention (14 days)	Low

Cash et al., 2014	age: *M* = 48.03, *SD* = 10.09, range: 23-74; gender: 0% male	Risk (diagnosed: fibromyalgia)	Mindfulness based stress reduction; (*n* = 41), (FA / MBI)	Passive: Wait-list control; (*n* = 27)	20 hours (8 sessions through 8 weeks	Six saliva samples at waking, 45-minutes post-waking (+45 m), 12:00, 16:00, 20:00 hours, and bedtime through 2 consecutive days to calculate diurnal mean	-	Some concerns
Cash et al., 2014	age: *M* = 48.03, *SD* = 10.09, range: 23-74; gender: 0% male	Risk (diagnosed: fibromyalgia)	Mindfulness based stress reduction; (*n* = 41), (FA / MBI)	Passive: Wait-list control; (*n* = 27)	26 hours (8 sessions through 8 weeks + half day meditation retreat (6hr))	Six saliva samples at waking, 45-minutes post-waking (+45 m), 12:00, 16:00, 20:00 hours, and bedtime through 2 consecutive days to calculate diurnal mean	two months after the intervention (60 days)	Some concerns
Chhatre et al., 2013	age: *M* = 49.7, *SD* = 7.1 (intervention); *M* = 50.0 *SD* = 4.4 (control), range: over 18; gender: 19% male	Risk (diagnosed: HIV infection)	Transcendental meditation; (*n* = 11), (TM)	Active: Healthy eating education program (HE); (*n* = 9)	18 hours (9 sessions through 24 weeks with decreasing frequency)	One blood sample between 9:00-10:00; (a.m.)	-	Some concerns
Fan et al., 2013	age: *M* = 20.87, *SD* = 0.26, range: no data; gender: 47% male	No risk	Integrative body–mind training (IMBT); (*n* = 17), (B-M)	Active: Relaxation training (RT); (*n* = 17)	8.3 hours (20 sessions through 4 weeks)	One saliva sample after a rest phase before the Mental arithmetic task between 14:00-18:00; (p.m.)	Within five days (5 days)	Some concerns
Flook et al., 2013	age: *M* = 43.06, *SD* = 9.87, range: 25-56; gender: 11% male	No risk	Modified Mindfulness-Based Stress Reduction (mMBSR) adapted for teachers; (*n* = 10), (FA / MBI)	Passive: Wait-List control; (*n* = 8)	26 hours (8 sessions through 8 weeks + a day-long immersion (6 hr.))	One saliva sample 30 minutes after waking on three consecutive working days; (a.m.)	Within one or two week (10.5 days)	Some concerns
Frisvold, 2009	age: *M* = 48.3, *SD* = 5.0 (intervention), *M* = 48.4, *SD* = 6.2 (control), range: 39-57; gender: 0% male	Risk (highly stressed)	Mindfulness Based Stress Reduction (MBSR); (*n* = 20), (FA / MBI)	Active: Midlife health education; (*n* = 18)	26 hours (8 sessions through 8 weeks + full day retreat of silent meditation)	One blood sample at 7:00 after 12 hours fasting; (a.m.)	16^{th} week after starting the 8-week program (56 days)	Some concerns
Gagrani et al., 2018	age: *M* = 57.28, *SD* = 9.37, range: no data; gender: 65% male	Risk (diagnosed: primary open angle glaucoma (POAG))	Meditation daily; (*n* = 30), (FA / MBI)	Passive: Wait-List control (Standard	31.5 hours (41 sessions through 6 weeks)	One blood sample at 8:00; (a.m.)	24 hours (1 day)	Some concerns

				medical treatment); (*n* = 30)				
Gainey et al., 2016	age: *M* = 58, *SD* = 10.39 (intervention), *M* = 63, *SD* = 6.63 (control), range: 50-75; gender: 17% male	Risk (diagnosed: Type 2 diabetes)	Buddhism-based walking meditation; (*n* = 12), (B-M)	Active: Traditional walking; (*n* = 11)	30 hours (36 sessions through 12 weeks)	One blood sample after 8 hours of overnight fasting; (a.m.)	-	Some concerns
Gex-Fabry et al., 2012	age: *Mdn*: 46, range: 24-66; gender: 29% male	Risk: (diagnosed: History of recurrent major depressive disorder)	Mindfulness-based cognitive therapy (MBCT) plus treatment as usual (TAU); (*n* = 22), (FA / MBI)	Passive: Treatment as usual (TAU) for depression relapse prophylaxis; (*n* = 22)	16 hours (8 sessions through 8 weeks)	Seven saliva samples at awakening, 15, 30, 45 and 60 minutes post-awakening, 3 a.m. and 8 p.m. to calculate AUCg	-	Seome concerns
Goldberg et al., 2014	age: *M* = 42.2, *SD* = 11.4, range: 25-65; gender: 44% male	Risk (smoking in the first half of the intervention (smoking cessation program))	Mindfulness training for smokers (MTS); (*n* = 10), (FA / MBI)	Active: Cognitive-behavioral therapy (CBT); (*n* = 8)	20 hours (8 sessions through 7 week)	1 cm hair samples 1 month after quit attempt	One month after the end of the intervention (hair), (we used 15 days)	Some concerns
Gotink et al., 2017	age: *M* = 43.2, *SD* = 14.1 (intervention); *M* = 43.2, *SD* = 13,7 (control), range: 18-65; gender: 54% male	No risk (structural heart disease)	Online mindfulness training; (*n* = 107), (FA / MBI)	Passive: Usual care alone (UC); (*n* = 98)	6 hours (12 sessions through 12 weeks)	Hair sample from scalp	8,5 months after the end of the intervention (hair) (we used 255 days)	Some concerns
Hsiao et al., 2016	age: *M* = 52.5, *SD* = 8.4 (intervention), *M* = 47.9, *SD* = 6.1 (control), range: 18-65; gender: 0% male	Risk (breast cancer survivors)	Couples support group with mindfulness (CSG); (*n* = 10), (M-B)	Active: Individual support program (ISP); (*n* = 10)	16 hours (8 sessions through 8 weeks)	Six saliva samples during the day (at wake up, 30 and 45 min after waking up, at 12:00 17:00 21:00) to calculate diurnal mean)	-	Some concerns
Hsiao et al., 2016	age: *M* = 52.5, *SD* = 8.4 (intervention), *M* = 47.9, *SD* = 6.1 (control); range: 18-65, gender: 0% male	Risk (breast cancer survivors)	Couples support group with mindfulness (CSG); (*n* = 10), (M-B)	Active: Individual support program (ISP); (*n* = 10)	16 hours (8 sessions through 8 weeks)	Six saliva samples during the day (at wake up, 30 and 45 min after waking up, at 12:00 17:00 21:00) to calculate diurnal mean)	Three, six and 12 months after the end of the intervention (90, 180 and 365 days)	Some concerns

Jedel et al., 2014	age: *M* = 46.04, *SD* = 12.80 (intervention), *M* = 39.68, *SD* = 11.06 (control), range: 18-70; gender: 44% male	Risk (diagnosed: (Inactive) Ulcerative Colitis)	Mindfulness Based Stress Reduction (MBSR); (*n* = 16), (FA / MBI)	Active: Attention control; (*n* = 13)	20 hours (8 sessions through 8 weeks)	Urine samples through a 24-hour period to calculate 24-Hour cortisol in µg	12 months (365 days)	Some concerns
Jensen et al., 2011	age: *M* = no data, range 20-36; gender: 38% male	No risk	Mindfulness-Based Stress Reduction (MBSR); (*n* = 14), (FA / MBI)	Active: Non-mindfulness Stress Reduction (NMSR); (*n* = 13)	27 hours (8 sessions through 8 weeks + 7 hours retreat)	Five saliva samples: first upon awakening, and Samples 2–5every 15 min for the subsequent hour to calculate AUCg; (a.m.)	-	Some concerns
Jensen et al., 2011	age: *M* = No data, range 20-36; gender: 38% male	No risk	Mindfulness-Based Stress Reduction (MBSR); (*n* = 14), (FA / MBI)	Passive: Inactive controls (incentive and No incentive analysed together =collapsed inactive controls (CICO)); (*n* = 14)	27 hours (8 sessions through 8 weeks + 7 hours retreat)	Five saliva samples: first upon awakening, and Samples 2–5every 15 min for the subsequent hour to calculate AUCg; (a.m.)	-	Some concerns
Jung et al., 2015	age: *M* = 66.27, *SD* = 8.36 range: no data; gender: 48% male	Risk (diagnosed: type 2 diabetes mellitus)	Korean mindfulness-based stress reduction (K-MBSR) + PE; (*n* = 21), (FA / MBI)	Passive: Patient education only (PE); (*n* = 17)	20 hours (16 sessions through 8 weeks)	One blood sample (no more information)	-	Some concerns
Jung et al., 2015	age: *M* = 66.27, SD = 8.36 range: no data; gender: 48% male	Risk (diagnosed: type 2 diabetes mellitus)	Korean mindfulness-based stress reduction (K-MBSR) + PE; (*n* = 21), (FA / MBI)	Active: Walking exercise program + PE; (*n* = 18)	20 hours (16 sessions through 8 weeks)	One blood sample (no more information)	-	Some concerns
Kim et al., 2013	age: *M* = 47.6, *SD* = 7.7 (intervention), M = 45.0, SD = 10.0 (control) range: no data; gender: 5% male	Risk: (participants with subclinical features of PTSD)	Mind-body intervention (MBX); (*n* = 11), (M-B)	Passive: Control; (*n* = 11)	16 hours (16 sessions through 8 weeks)	One blood sample around 8:00; (a.m)	-	Some concerns
Lipschitz et al., 2013	age: *M* = 50.8, *SD* = 9.10 (intervention), *M* = 51.6, *SD* = 10.7 (control), range: 18-75; gender: 21% male	Risk (cancer survivor)	Mindfulness meditation (MM) (*n* = 20), (FA / MBI)	Active: Sleep Hygiene Education (SHE); (*n* = 18)	No data (3 sessions through 3 weeks)	Four saliva samples (Post-awake, Noon, Afternoon (5 p.m.), Evening (10 p.m.)) to calculate diurnal mean	Minimum of one week following the final session (7 days)	Some concerns

Lipschitz et al., 2013	age: *M* = 50.8, *SD* = 9.10 (intervention), *M* = 55.4, *SD* = 9.6 (control), range: 18-75 gender: 27% male	Risk (cancer survivor)	Mindfulness meditation (MM) (*n* = 20), (FA / MBI)	Active: Mind-Body Bridging (MBB); (*n* = 19)	No data (3 sessions through 3 weeks)	Four saliva samples (Post-awake, Noon, Afternoon (5 p.m.), Evening (10 p.m.)) to calculate diurnal mean	Minimum of one week following the final session (7 days)	Some concerns
Marshall et al., 2018	age: *M* = 56.38, *SD* = 14.57, range: 38-73; gender: 63% male	No risk (but: diagnosed: aphasia after stroke)	Mindfulness meditation (*n* = 5), (FA / MBI)	Active: Mind wandering (*n* = 3)	0.75 hours (3 sessions through 3 days)	One saliva sample in the afternoon; (p.m.)	1 day after the 3rd session (1 day)	Some concerns
MacLean et al., 1997	age: *M* = 25, range: 18-32; gender: 100% male	No risk	Transcendental Meditation ™ program; (*n* = 16), (TM)	Active: Stress education control (SEC); (*n* = 13)	65.3 hours (124 sessions through 16 weeks)	One blood sample between 8:30-9:30 after 12 hr. fasting before a TSST; (a.m.)	-	Some concerns
Malarkey et al., 2013	age: *M* = 51, *SD* = 7.67 (intervention), *M* = 49, *SD* = 7.72 (control), range: no data; gender: 13% male	Risk (elevated CRP levels or/and have risk for cardiovascular disease, or depression hypertension hyperlipidaemia, gastroesophageal reflux disease (GERD), osteoarthritis, diabetes)	Low dose Mindfulness-Based Intervention (MBI-ld); (*n* = 84), (FA / MBI)	Active: Education Control; (*n* = 86)	10 hours (8 sessions through 8 weeks + 2 hours retreat)	Four saliva samples 20 min post rising, noon, 5 p.m., and bedtime on three days (days 2, 8 and 14 of a 2-week period)	In a two-week period after the intervention (14 days)	Some concerns
Nyklíček et al., 2013	age: *M* = 46.1, *SD* = 10.6, range: no data; gender: 29% male	Risk (elevated stress levels)	Mindfulness-Based Stress Reduction; (*n* = 32), (FA / MBI)	Passive: Wait-list control; (*n* = 30)	20 hours (8 sessions through 8 weeks)	One saliva sample after a resting period before a computerized stress session in the afternoon; (p.m.)	-	Some concerns
Oken et al., 2010	age: *M* = 62.50, *SD* = 11.61, (intervention), *M* = 67.09, *SD* = 8.36 (control), range: 45-85; gender: 19% male	Risk (dementia caregivers)	An adapted meditation intervention based on MBSR and MBCT; (*n* = 10), (FA / MBI)	Active: A program adapted from Powerful Tools for Caregivers (PTC): „Education”; (*n* = 11)	9 hours (6 sessions through 7 weeks)	Three saliva samples within 5 minutes after awakening, 30 minutes later before eating, bedtime, (10–11 p.m.) to calculate diurnal mean	Within three weeks after the last class (21 days)	Some concerns

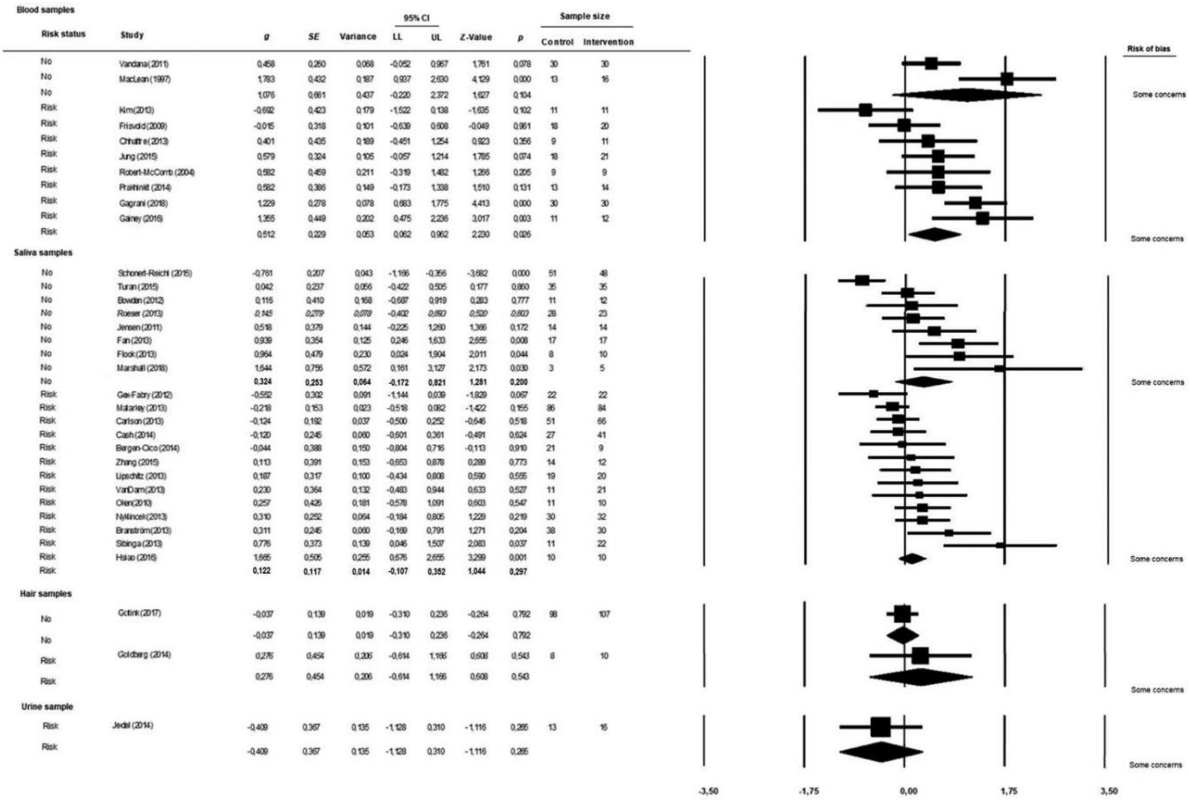
Oken et al., 2010	age: *M* = 62.50, *SD* = 11.61, (intervention), *M* = 63.80, *SD* = 7.93 (control), range: 45-85; gender: 19% male	Risk (dementia caregivers)	An adapted meditation intervention based on MBSR and MBCT; (*n* = 10), (FA / MBI)	Passive: Respite-only; (*n* = 10)	9 hours (6 sessions through 7 weeks)	Three saliva samples within 5 minutes after awakening, 30 minutes later before eating, bedtime, (10–11 p.m.) to calculate diurnal mean	Within three weeks after the last class (21 days)	Some concerns
Prakhinkit et al., 2014	age: *M* = 74, *SD* = 6.36 (intervention); *M* = 74.8, *SD* = 6.13, (control) range: 60-90; gender: 0% male	Risk (mild-to-moderate depressive symptoms)	Buddhism-based walking meditation (BWM), (*n* = 14), (B-M)	Active: Traditional walking exercise (TWE); (*n* = 13)	15 hours (36 sessions through 12 weeks)	One blood sample after 8 h overnight fasting; (a.m.)	-	Some concerns
Prakhinkit et al., 2014	age: *M* = 74, *SD* = 6.36; (intervention), *M* = 81.0, *SD* = 6.14 (control), range: 60-90; gender: 0% male	Risk (mild-to-moderate depressive symptoms)	Buddhism-based walking meditation (BWM), (*n* = 14), (B-M)	Passive: Sedentary control; (*n* = 13)	15 hours (36 sessions through 12 weeks)	One blood sample after 8 h overnight fasting; (a.m.)	-	Some concerns
Robert McComb et al., 2004	age: *M* = 60, *SD* = 6.3, range: no data; gender: 0% male	Risk (history of heart disease)	Mindfulness-Based Stress Reduction; (*n* = 9), (FA / MBI)	Passive: Wait-list control; (n = 9)	16 hours (8 sessions through weeks)	One blood sample in the morning after 12 hr. fasting (a.m.)	-	High
Roeser et al., 2013	age: *M* = 50, *SD* = no data, range 28-59 (intervention), M = 46 SD = no data, range: = 29-63 (control); gender: 10% male	No risk	Mindfulness Training Program (*n* = 26), (FA / MBI)	Passive: Waitlist-control (n = 32)	36 hours (11 sessions through 8 week)	Three saliva samples at awakening, 30min after awakening, and at bedtime	-	Some concerns
Roeser et al., 2013	age: *M* = 50, *SD* = no data, range 28-59 (intervention), *M* = 46 *SD* = no data, range: = 29-63 (control); gender: 10% male	No risk	Mindfulness Training Program (*n* = 26), (FA / MBI)	Passive: Waitlist-control (n = 32)	36 hours (11 sessions through 8 week)		Three months follow up (90 days)	Some concerns
Schonert-Reichl et al., 2015	age: *M* = 10.24, *SD* = 0.53, range: 9.00-11.16; gender: 46% male	No risk	MindUP program (a mindfulness-based education social and emotional learning (SEL) program); (*n* = 48), (FA / MBI)	Active: Regular social responsibility program; (*n* = 51)	9 hours (12 sessions through 12 weeks)	Three saliva samples at 9:00 AM 11:30 a.m. and 2:30 p.m. to calculate daily mean	Within one week after the intervention (7 days)	Some concerns

Sibinga et al., 2013	age: *M* = 12.5, *SD* = no data, range: 11-14; gender: 100% male	Risk (low income)	Mindfulness-Based Stress Reduction; (*n* = 22), (FA / MBI)	Active: Health education (Healthy Topics—HT); (*n*= 11)	10 hours (12 sessions through 12 weeks)	Three saliva samples at awakening, 60 minutes post-awakening and bedtime, to calculate AUCg	Within two weeks after the intervention (14 days)	Some concerns
Turan et al., 2015	age: *M* = 40.61, *SD* = 10.28, range: 25-60; gender: 0% male	No risk	Meditation and emotional skills training; (*n* = 35), (FA / MBI)	Passive: No treatment control; (*n* = 35)	42 hours (4 all-day and 4 evening sessions through 8 weeks)	One saliva sample following a 20 min resting phase before a TSST	On the concluding occasion (0 days)	Some concerns
Turan et al., 2015	age: *M* = 40.61, *SD* = 10.28, range: 25-60; gender: 0% male	No risk	Meditation and emotional skills training; (*n* = 35), (FA / MBI)	Passive: No treatment control; (*n* = 35)	42 hours (4 all-day and 4 evening sessions through 8 weeks)	One saliva sample following a 20 min resting phase before a TSST	Five months after the intervention (150 days)	Some concerns
Van Dam, 2013	age: *M* = 40.0, *SD* = 13.3 (intervention), *M* = 36.9, *SD* = 14.2 (control) range: 28-65; gender: 32% male	Risk (community sample with undiagnosed, but significant, symptoms of anxiety, depression, and stress)	Mindfulness meditation training (MMT); (*n* = 21), (FA / MBI)	Passive: Wait-list control (NT); (*n* = 11)	26 hours (8 sessions through 8 weeks + 6-hour retreat)	One saliva sample before a TSST	One and a half months after the intervention (45 days)	Some concerns
Vandana et al., 2011	age: *M* = no data, range: 18-21; gender: 19% male	No risk	Integrated Amrita Meditation (IAM); (*n* = 30), (TM)	Active: Progressive Muscle Relaxation (PMR); (*n* = 31)	14.93 hours (32 sessions through 8 weeks)	One blood sample at 8:00; (a.m.)	One day	Some concerns
Vandana et al., 2011	age: *M* = no data, range: 18-21; gender: 18% male	No risk	Integrated Amrita Meditation (IAM); (*n* = 30), (TM)	Passive: No treatment control; (*n* = 28)	14.93 hours (32 sessions through 8 weeks)	One blood sample at 8:00; (a.m.)	One day	Low
Zhang and Emory, 2015	age: *M* = 25.3, *SD* = 4.6, range: 18-45; gender: 0% male	Risk (pregnant)	Mindful Motherhood; (*n* = 12), (FA / MBI)	Passive: Treatment as usual (TxAU); (*n* = 14)	(8 sessions through 4 weeks)	One saliva sample between 8:30 a.m. and 12:00 p.m. before an audio clip of a baby’s cry (a „stress” reactivity test)	-	Some concerns

We investigated the efficacy of meditation interventions for different at-risk samples. Three studies included participants with a mental problem and showed no effects of the interventions. Five studies included participants with a somatic illness. In these studies the effect was large and significant. Furthermore, we checked the effect of methodological differences between the primary studies. To test the effect of the type of control group we excluded three studies (Jung et al., 2015; Prakhinkrit et al., 2014; Vandana et al., 2011)) that used both an active and a passive control condition. In contrast to active control groups, there was a large, marginally significant effect of meditation intervention, while compared to passive controls, the effect size was medium-sized and non-significant. We did not have enough statistical power to compare these subgroups. One study did not report information about the time of sampling (Jung et al., 2015), while the others took samples before noon (for more details and the results of subgroup analyses see Table 3 and Figure 2 and 3).

Figure 2.

Forest plot for all included studies



Note. g = Hedges' g; CI = confidence interval, LL = lower limit; UL = upper limit

Table 3.

Effects of meditation interventions on change in blood cortisol levels in the different subgroup moderator analyses for methodological differences in the primary studies

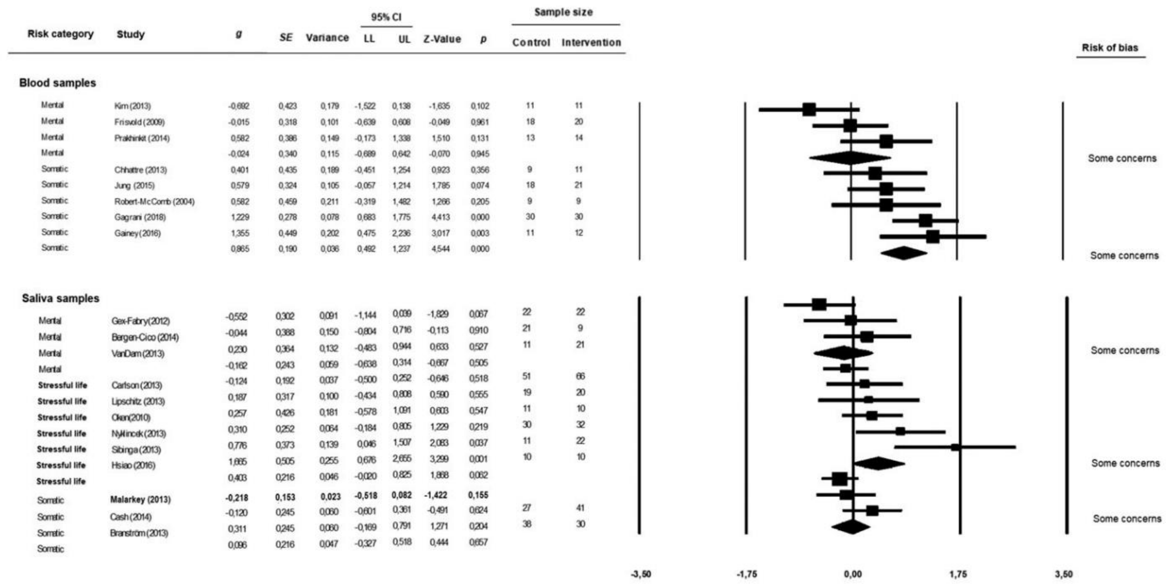
Moderator	***g***	***k***	***n***	***SE***	**95% CI**		***p***	***Q* statistic**			***I*² statistic**		
					LL	**UL**		***Q***	***df (Q)***	***p***	***I*²**	**95% CI LL**	**95% CI UL**
Risk status													
No risk	1.08	2	118	0.66	-0.22	2.37	.104	6.92	1	.009	86%	0%	99%
At-risk	0.51	8	277	0.23	0.06	0.96	.026	21.06	7	.004	67%	0%	93%
Type of problem in case of at-risk samples													
Mental	-0.02	3	100	0.34	-0.69	0.64	.945	4.96	2	.08	60%	0%	97%
Somatic	0.87	5	177	0.19	0.49	1.24	<.001	5.18	4	.26	23%	0%	87%
Stressful life situation													
Control condition													
Active	0.85	4	110	0.44	-0.002	1.70	.051	13.94	3	.003	78.48	0%	97%
Passive	0.40	3	100	0.59	-0.76	1.56	.500	14.39	2	.001	86.10	0%	98%
Sampling time													
AM	0.63	9	339	0.23	0.17	1.08	.007	28.97	8	<.001	72.39	0%	93%
PM													

Note. g = Hedges' g; CI = confidence interval, LL = lower limit; UL = upper limit

We had sufficient statistical power to run meta-regression analyses (Table 4). Intervention duration had a significant positive effect on the effect size after excluding one outlier (MacLean, 1997) suggesting that longer meditation interventions had larger effects on participants' blood cortisol levels. It seems that interventions longer than 1200 minutes seem to be most effective (see Figure 4). The other interesting finding is that these programs are more effective for men (see Figure 5). We were unable to test the effect of the elapsed time after the intervention until the post-test cortisol sampling because only three studies reported on this information. There was no effect of age (see Table 4.).

Figure 3.

Forest plot for subgroups in the moderator of risk status of the participants



Note. g = Hedges' g; CI = confidence interval, LL = lower limit; UL = upper limit

Table 4.

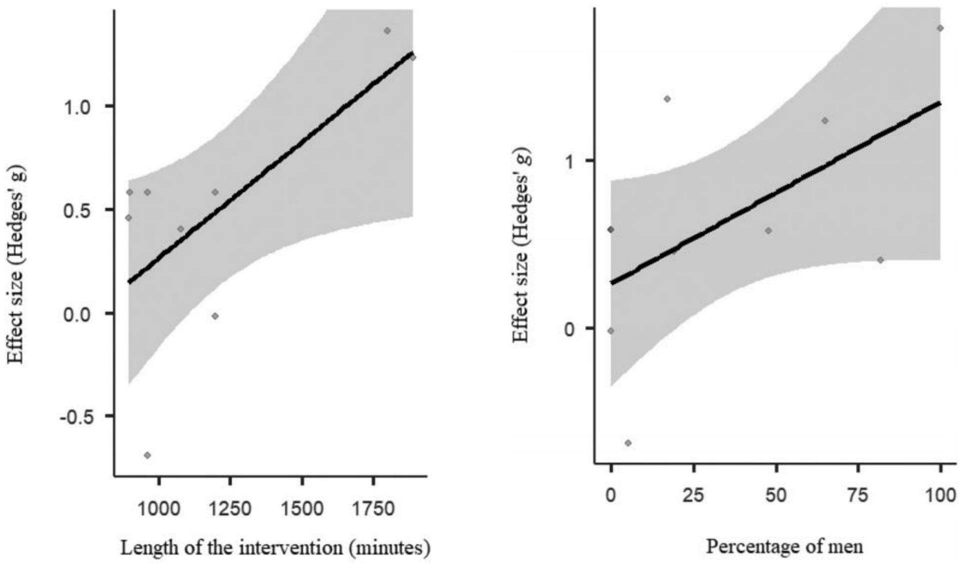
Results of meta-regression analyses for methodological differences in the primary studies that applied blood cortisol sampling.

Regression	Coefficient	*k*	*SE*	95 %CI		*p*
				LL	UL	
Gender distribution	0.0114	10	0.0049	0.0018	0.0209	.020
Mean age	-0.0022	10	0.0133	-0.0284	0.0239	.867
Total intervention time	0.0010	9	0.0004	0.0003	0.0018	.009
Elapsed time after intervention	-	-	-	-	-	-

Note. CI = confidence interval, LL = lower limit; UL = upper limit

Figure 4. and 5.

Effect of the length of the intervention on cortisol levels in blood samples



3.4.2 Effect of meditation on salivary cortisol

There was one outlying study (Stefanaki et al., 2015) based on the standardized residuals. After excluding that study, we synthetized the results of 21 trials including data of 1163 participants. For the characteristics of the studies see Table 2. Nineteen of these studies utilized a meditation program based on mindfulness and used a focused attention (FA) type meditation, while one used mind-body (M-B) (Hsiao et al., 2016) and an other study a body-mind (B-M) intervention (Fan et al., 2013). Only five studies (24%) took saliva samples on more days: one of them sampled one per day, while two sampled four and another two on five occasions during the day. Sixteen studies (76%) sampled on only one day and half of them sampled on three or more occasions per day, in seven studies samples were taken on only one occasion per day, while one study sampled twice on the sampling day. From all the included studies, only three synchronized all sampling times to waking times. The classic fail-safe N method showed that 11 non-significant studies would turn the average effect non-significant. Thus, according to Rosenthal's criterion, the average effect was not robust. The Duval and Tweedie's trim and fill method showed eight trimmed studies and the adjusted effect size was g = -0.10 and non-significant (95% CI = [-0.33; -0.13). Risk of bias analyses in these studies indicated some concerns and only one study's risk was low (see Table 2). Meditation had a small and marginally significant effect on change in cortisol levels in salivary samples (g = 0.18, k = 21, SE = 0.11, 95% CI = [-0.04, 0.40], p = .102). The effect was heterogeneous (Q (20) = 56.77, p < .001, I^2= 64.77, 95% CI = [11, 86]). Estimating the effect with the weight function model resulted in a negative effect (g = -0.10, 95% CI = [-0.28, 0.08) and the likelihood of this model was -1.73 and -2.50 for the original model. The likelihood ratio test was non-significant (p = .21) indicating that the original model is as good as the adjusted one. After excluding the two studies that reported on the results of participants under 18 years (Schonert-Reichl et al., 2015; Sibinga et al., 2013) the effect was similar in size and marginally significant (g = 0.20, k = 19, SE = 0.10, 95% CI = [-0.002, 0.398], p = .052). Again, this was a heterogeneous effect (Q (18) = 37.02, p = .005) I^2= 51.38, 95% CI = [0, 83].

Furthermore, we assessed the moderator of the samples' risk status. For both at-risk and no-risk samples the effect was small and not significant. We had insufficient statistical power to contrast the above-mentioned average effect sizes. We also investigated the efficacy of meditation interventions for different at-risk samples. For the results of subgroup analyses see Table 5 and Figure 3. Three studies reported on participants with a diagnosis or symptoms of a mental illness and three on somatic problems. On average, there was no significant effect of meditation either for the samples with a mental disorder or in the studies including participants with somatic issues. In the six studies that tested samples in stressful life situation a marginally significant, medium effect appeared. The statistical power was not enough to compare the above-mentioned categories. One study with a sample at a risk for elevated cortisol levels including pregnant women (Zhang & Emory, 2015) could not be categorized into the above-mentioned categories.

To check the methodological differences between the primary studies we, again, ran subgroup analyses (see Table 5). For testing the effect of the type of control group, we excluded those studies that used both an active and a passive control condition (Jensen et al., 2011; Oken et al., 2010). There were no significant effects of meditation compared either to active or passive control groups and we had insufficient statistical power to contrast them. In case of those four studies that reported the time of sampling, studies in which they collected samples before noon showed a small and significant effect, and in those three studies that sampled in the afternoon the effect was large and also significant. Those 12 studies that sampled both a.m. and p.m. showed an effect that was near to zero and non-significant (see Table 5). There was no sufficient statistical power for contrasting. Two studies did not report this information (Turan et al., 2015; Van Dam, 2013). Additionally, we tested the effect of the number of cortisol samples that were collected in the primary studies. In case of the 13 studies that collected multiple samples, 12 of them collected them both a.m. and p.m. (the same group as mentioned above), while in one study (Jensen et al., 2011) they collected samples before noon. There was, no significant effect in those studies that collected multiple samples. In those studies that collected only one sample during a day (three sampled a.m., three sampled p.m. and two did not gave any information (Turan et al., 2015; Van Dam, 2013) the effect was medium-sized and significant (see Table 5). There was not enough statistical power to contrast them.

Table 5.

The effect in change of salivary cortisol. Results of subgroup moderator analyses for methodological differences in the primary studies

Moderator	*g*	*k*	*n*	*SE*	95% CI		*p*	*Q statistic*			*I^2 statistic*		
					LL	UL		*Q*	*df (Q)*	*p*	*I^2*	95% CI LL	95% CI UL
Risk status													
No risk	0.32	8	354	0.25	-0.17	0.82	.200	31.46	7	<.001	78%	13%	94%
At-risk	0.12	13	809	0.12	-0.11	0.35	.297	25.31	12	.013	53%	0%	87%
Type of problem in case of at-risk samples													
Mental	-0.16	3	106	0.24	-0.64	0.31	.505	2.91	2	.233	31%	0%	94%
Somatic	-0.05	3	306	0.16	-0.36	0.26	.765	3.40	2	.184	41%	0%	94%
Stressful life situation	0.40	6	371	0.22	-0.02	0.83	.062	13.75	5	.017	64%	0%	93%
Control condition													
Active	0.22	8	614	0.23	-0.22	0.66	.323	38.17	7	<.001	82%	33%	94%
Passive	0.13	11	477	0.12	-0.09	0.36	.246	14.64	10	.146	32%	0%	83%
Sampling time													
AM	0.40	4	153	0.17	0.06	0.73	.020	2.15	3	.541	0%	0%	74%
PM	0.74	3	104	0.33	0.10	1.39	.024	4.14	2	.126	52%	0%	96%
AM and PM	0.01	12	804	0.14	-0.27	0.29	.951	33.37	11	<.001	67%	0%	90%
Sampling procedure													
One sample / day	0.39	8	320	0.14	0.12	0.66	.005	9.57	7	.215	27%	0%	85%
More samples	0.04	13	843	0.14	-0.23	0.32	.756	36.09	12	.001	67%	0%	90%

Note. g = Hedges' g; CI = confidence interval, LL = lower limit; UL = upper limit

We had enough statistical power for all the meta-regression analyses (Table 6). There were no effects of gender distribution, the age of the participants or the total time of the intervention. In case of the elapsed time after the intervention we excluded one study (Hsiao et al., 2016) because it was an outlier in this regard (the latest sampling was after one year). The effect was non-significant (see Table 6 and Figure 6).

Table 6.

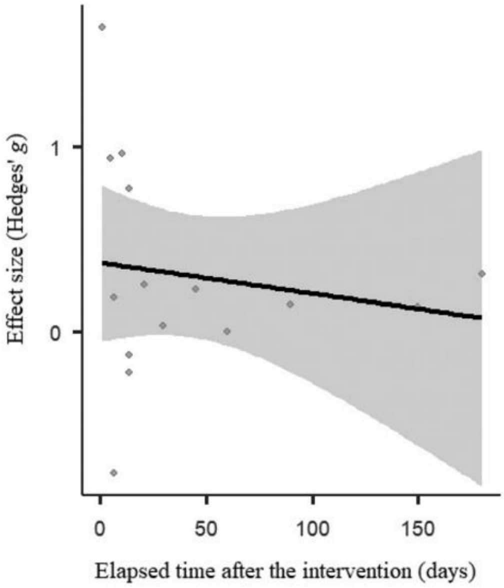
Results of meta-regression analyses for methodological differences in the primary studies that assessed salivary cortisol

Regression	**Coefficient**	***k***	***SE***	**95 %CI**		***p***
				LL	UL	
Gender distribution	0.0024	21	0.0042	-0.0059	0.0107	0.572
Mean age	0.0023	21	0.0081	-0.0136	0.0182	0.775
Total intervention time	0.0000	19	0.0002	-0.0004	0.0004	0.981
Elapsed time after intervention	0.0001	15	0.0023	-0.0043	0.0045	0.962

Note. CI = confidence interval, LL = lower limit; UL = upper limit

Figure 6.

Effect of the elapsed time after the end of the intervention in saliva samples



3.4.3 Comparison of results from blood and saliva samples

As the results show, a significant main effect of meditation interventions was found in the studies that utilized blood samples. More specifically, these interventions had a large effect for samples with a somatic illness. In contrast, studies assessing saliva cortisol showed no significant main effect of meditation interventions except for the subset of studies that sampled people living in stressful life situations. Thus, a plausible explanation for the differential main effects of meditation interventions on blood and saliva cortisol is that 80% of the studies focusing on blood cortisol included at-risk samples and, more specifically, half of the studies included participants with a somatic illness (for whom a large effect was found). On the other hand, only 62% of the studies focusing on saliva samples included at-risk participants, more specifically, 14% of the studies recruited participants with a somatic illness and 29% included samples living in stressful life situations (for whom a moderate-sized effect was found). In sum, the overall large effect found on blood samples might be explained by the fact that the proportion of studies with at-risk samples (and more specifically, patients with a somatic illness) was larger for these studies as compared to trials utilizing saliva samples to assess cortisol levels.

Another possible explanation is that 90% of the blood samples were taken before noon, in which studies the effect was medium-sized and significant. In contrast, studies that took saliva samples before noon also showed a medium-sized and significant effect. However, half of these studies included at-risk samples. If we look at those studies that collected saliva samples both before and afternoon, there was no effect. Nine of these studies (75%) focused on at-risk samples. A puzzling finding is that saliva samples taken in the afternoon showed a large and significant effect. In sum, although no clear pattern emerges, the timing of cortisol sampling could have an effect on the results.

3.4.4 Effect of meditation on hair cortisol

Only two included studies reported results based on hair cortisol. Mindfulness-based and focused attention (FA) interventions were used in both studies. The average effect size of the two studies including a total of 223 participants showed no effect (g = -0.01, k = 2, SE = 0.13, 95% CI = [-0.27, 0.25], p = .94), which was a homogeneous result (Q (1) = 0.43, p < .510, I^2= 0.00). Gotink and colleagues (2017) reported results of participants with no risk (structural heart disease) and found a null effect (g = -0.04, k = 1, SE = 0.14, 95% CI = [-0.31, 0.24], p = .79) compared to a passive control condition. The overall risk of bias in this study indicated some concerns. Goldberg and colleagues (2014) reported results of at-risk participants as they were in the middle of smoking cessation. In this study there was a small and non-significant effect of the intervention (g = 0.28, k = 1, SE = 0.45, 95% CI = [-0.61, 1.16], p = .54) compared to an active control condition. There were some concerns regarding the risk of bias in this study.

3.4.5 Effect of meditation on urine cortisol

One study assessed the effects of a meditation intervention on urine cortisol of 29 participants (Jedel et al., 2014). In this study there was a non-significant, medium-sized negative effect (g = -0.41, k = 1, SE = 0.36, 95% CI = [-0.13, 0.31], p = .27) of the Mindfulness-Based Stress Reduction program compared to an active control condition in an at-risk sample of inactive ulcerative colitis patients. The risk of bias showed some concerns in this study.

4. Study 2:
Short mindfulness-based intervention has no effects on executive functions but may reduce baseline cortisol levels of boys in first-grade.

4.1 Aim of the study

Based on the results mentioned in the introduction and in Study 1, mindfulness-based interventions seem to have positive effects on executive function skills (Takacs & Kassai, 2019) and stress (Koncz et al., 2021a; Pascoe et al., 2017; Sanada et al., 2016), however, evidence regarding children is limited in both outcomes (see Study 1 (Koncz et al., 2021a) and (Takacs & Kassai, 2019)). Furthermore, such programs might thus have the potential to foster children's adaptation and performance in stressful life situations such as school entry (Groeneveld et al., 2013), based on the model of Creswell and Lindsay (2014) however, no studies to our knowledge have tested this. Accordingly, the present study aimed to test whether a short mindfulness-based intervention right before school entry can improve executive functions kills and lower children's stress levels upon school entry.

4.2 Hypotheses

H4: A short mindfulness-based program enhances children's executive function skills, specifically working memory and inhibitory control (Takacs & Kassai, 2019). We assumed that it might also have a positive effect on cognitive flexibility as meditation practices have been found to positively correlate with cognitive flexibility (Moore & Malinowski, 2009).

H5: The mindfulness program decreases children's morning cortisol levels compared to the control group (Koncz et al., 2021a; Pascoe et al., 2017; Sanada et al., 2016).

H6: The mindfulness intervention might protect children from elevated cortisol levels upon school entry on follow-up assessment.

H7: The mindfulness group would show lower cortisol reactivity to an acute stress situation on post-test (Brown et al., 2012).

4.3 Methods

4.3.1 Study approval

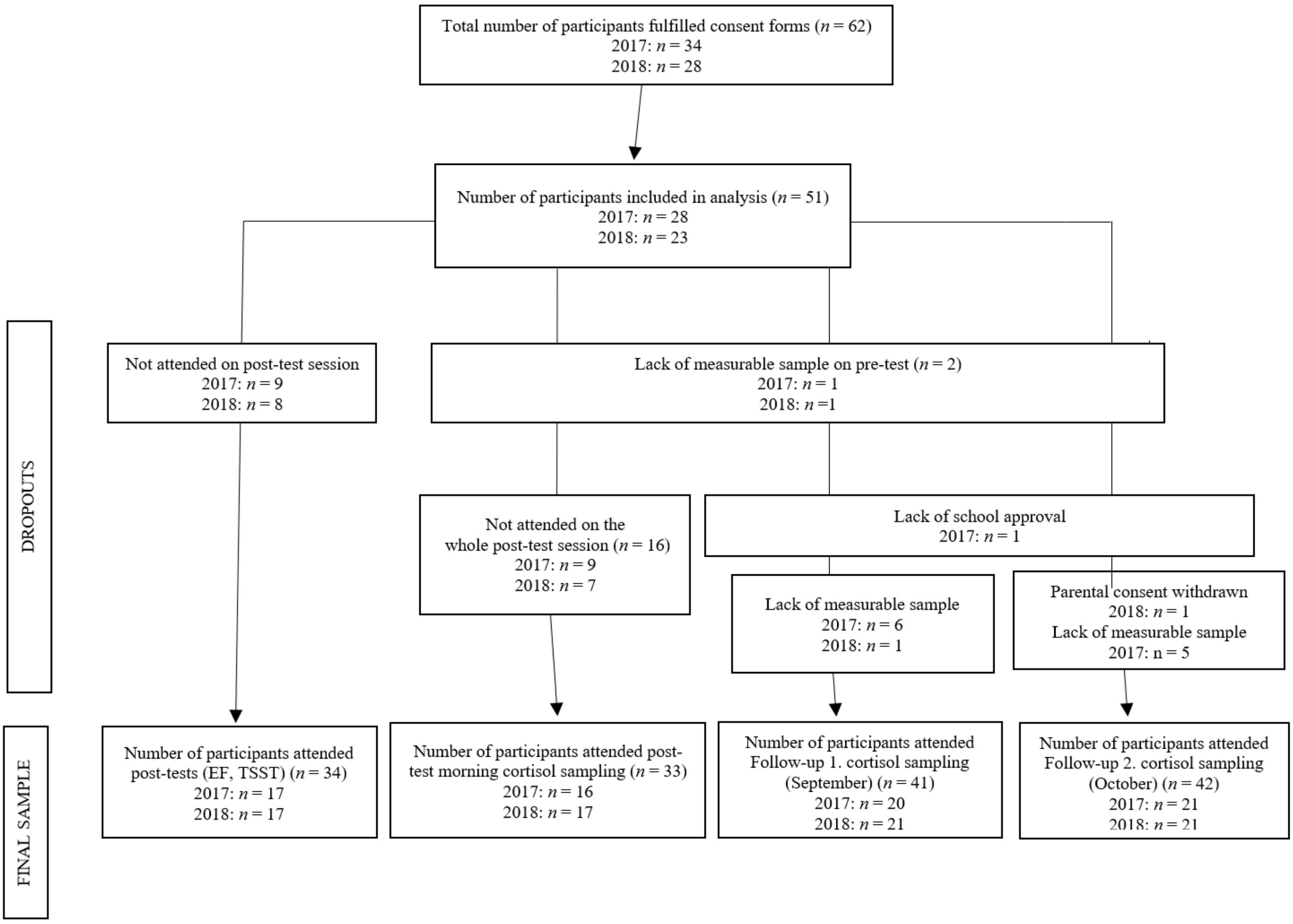
This study was approved by the Research Ethics Committee of the Faculty of Education and Psychology at the Eötvös Loránd University under the registration number 2017/208 and 2018/232.

4.3.2 Participants

Preschoolers facing school entry were recruited in eight state preschools in the capital of Hungary, Budapest, during the summer of 2017 and 2018. A total of 62 parents gave consent for their children to participate in the experiment. The inclusion criterion was the child not having any psychological or psychiatric problems or any somatic illnesses that can have an impact on cortisol levels (e.g., type II diabetes). Additionally, we excluded 10 children because they were twins of participants (n = 2), non-native speaker of Hungarian (n = 1), children who took part on less than 3 intervention sessions due to absence from preschool (n = 5), children who did not complete executive function tests and the cortisol sampling procedure because absence from preschool on the pre-test week (n = 2) and another child who refused to participate on the post-test session (n = 1). The final sample consisted of 51 participants aged 71 to 94 months (M = 81.90, SD = 5.45). 41% of the sample was male.

Figure 7.

Number of participants at each timepoint



The socioeconomic status of the participants was most likely close to the average Budapest, the capital of Hungary, because all the participants were recruited from state preschools from average SES districts of Budapest. However, we have insufficient data to draw a firm conclusion, as most parents did not fill in the demographic questionnaire. For the exact number of the participants whose data could be included in each analysis see Figure 7 and for descriptive details of the intervention and control groups see Table 7 and 8.

Table 7.

Descriptive statistics of the participants in the control and intervention group who were included at least one of the analyses.

Gender	Control		Intervention	
	sample size	age months Mean (*SD*)	sample size	age months Mean (*SD*)
boy	13	80.00 (3.62)	8	84.25 (7.13)
girl	12	83.17 (5.46)	18	81.39 (5.57)

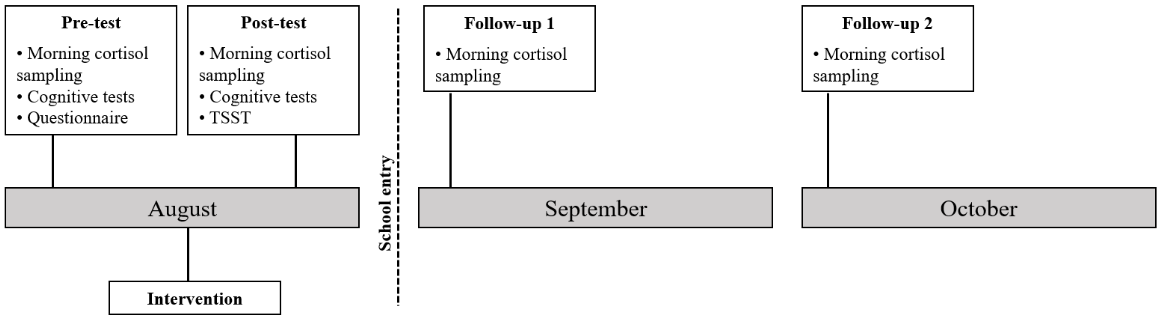
4.3.3 Design

A randomized controlled trial with a between-subject design was applied. Participants in the different preschool classrooms were matched based on age, gender and pre-test executive function performance and randomly assigned to the experimental or the passive control group. On a week in August preceding school entry in September the experimental group were taken out of the classroom for five 30-minute sessions of mindfulness-based training, while the passive control group attended regular preschool activities. Measurements were implemented on four time points: on the week before (pre-test) and the week after (post-test) the intervention in August in the kindergarten, on the first week of school (first week of September (FU1)) and one month after school entry (on the first week of October (FU2)). There was cortisol sampling in the morning upon arrival to the preschool on all four measurement points and an individual session including executive function tests on pre- and post-test. For the executive function tests different stimuli were used on pre- and post-test in order to avoid a learning effect. Additionally, we applied the Trier Social Stress Test adapted for children (TSST-C) on post-test following the executive function tests. On follow-up there was only cortisol sampling in the morning upon arrival to school (see Figure 8). Due to funding restraints, one cortisol sample per measurement occasion was taken from the children in the sample recruited in 2017 and one-one sample on three consecutive weekdays on each measurement occasion were taken from the children recruited in 2018. These samples were taken upon arrival to the institution on the mornings of

Tuesdays, Wednesdays and Thursdays in order to avoid effects of the beginning or the end of the (pre-)school week.

Figure 8.

Timeline of the experiment



4.3.4 Procedure

Morning cortisol samples were taken upon arrival at the preschool and school. Because children do not arrive at exactly the same time, we registered the time of sampling. To check the possible differences in the time of sampling (the one recorded value was used in case of data collected in 2017 and the average of the three days was used in case of the data from 2018) between the control and intervention group or between boys and girls, we ran repeated measures ANOVAs. Measurement points (e.g., pre-test, post-test, follow-up 1, follow-up 2) were used as the within-subject factor while gender and condition as between-subject factors. For children whose data could be included in the analyses regarding the change from pre- to post-test change in baseline cortisol (n = 33), the time of the sampling did not differ between the pre- (M = 8:33, SD= 0:35) and the post-test (M = 8:44, SD = 0:34) (F (1,29) = 2.27, p = .14), and there was also no main effect of gender (F(1,29) = 0.61, p = .44) or condition (F(1,29) = 0.44, p = .51). There was also no interaction effect between time x gender (F(1,29) = 1.20, p = .28), time x condition (F(1,29) = 0.34, p = .57), gender x condition (F(1,29) = 0.24, p = .63) or time x gender x condition (F(1,29) = 1.54, p = .23).

For children whose data could be included in the analysis regarding the change from pre-test to September (n = 41) samples were taken significantly earlier (F(1,37) = 76.40, p < .001) at the follow-up (at school) (M = 7:44, SD = 0:10) than on pre-test (in preschool) (M = 8:38, SD = 0:35). This is conceivable as school starts at 8 AM in most schools in [country name], while there is more flexibility in when children should arrive in preschool in the summer. There was no main effect of gender (F(1,37) = 0.11, p = .74) or condition (F(1,37) =

1.69, p = .20), or any interaction effects between time x gender (F(1,37) = 0.55, p = .46), time x condition (F(1,37) = 0.01, p = .91), gender x condition (F(1,37) = 1.37, p = .25) or time x gender x condition (F(1,37) = 1.11, p = .29).

Similarly, for children whose data could be included in the analysis regarding the change from pre-test to October (n = 42) the sampling time was also significantly earlier (F(1,38) = 77.30, p = <.001) at school (M = 7:46, SD = 0:09) than in preschool (M = 8:39, SD = 0:36). There was no main effect of gender (F(1,38) = 0.004, p = .95) or condition (F(1,37) = 1.21, p = .28) or any interaction between time x gender (F(1,37) = 0.49, p = .49), time x condition (F(1,37) = 0.01, p = .97) gender x condition (F(1,37) = 2.59, p = .12) or time x gender x condition (F(1,37) = 0.89, p = .35).

The executive function tests were implemented by research assistants in a quiet room in the kindergarten. Every session was recorded on a camcorder for the non-digitized tests to be coded by two independent coders afterwards. Disagreements were settled in discussion. The Go/NoGo test results were recorded by PsychoPy (ver. 1.85.1) (Peirce, 2007). At the beginning of the testing session children received a certificate for which they could choose stickers after completing each task as a means of motivation.

4.3.5 Intervention materials

The experimental group attended a one-week (5 sessions) story-based mindfulness program in the kindergarten in small groups (2-5 children). Every session was about 25-30 minutes long. The intervention was compiled by the authors based on commercially available books on mindfulness practices and relaxation storybooks for children. The program included breathing and sensory meditations, progressive muscle relaxation and yoga postures. For more details and references see appendix 4.

4.3.6 Measurement instruments

Baseline cortisol levels. Sample collection was implemented immediately after participants arrived to preschool or school in the morning. This was done on three consecutive weekdays in 2018 but only on one weekday in 2017 at each time point (on pre- and post-test and the two follow-up occasions). In order to measure cortisol reactivity, we also took saliva samples before and after the TSST-C procedure (for details see below). To collect saliva samples, sponge-ended plastic saliva samplers were used and samples were stored at -20 °C in Eppendorf tubes until cortisol assessment. To avoid interassay variation, samples from the same person were measured on the same plate with enzyme-linked immunosorbent assay (ELISA) method.

Stress reactivity. A stress induction task, the Trier Social Stress Test for Children, which is a modified version of Trier Social Stress Test reported by Gilissen and colleagues (2008) was used on post-test immediately after the executive function tests on post-test. In the first part of the task in order to simulate public speaking, the experimenter starts a story and asks the child to think for two minutes and finish that story in front of a camera. The experimenter says to the child that there are people sitting behind the camera who will evaluate his/her speech. In the second part of the test a puzzle is given to the child that is extremely difficult for this age group. The experimenter tells the child that they have four minutes to solve it and that his/her peers can easily do it. After four minutes, the experimenter indicates that the time has expired and says that now he/she is leaving the room to ask those people who are behind the camera about the child's storytelling performance. When the experimenter comes back, he/she tells the child that he/she was just as good at storytelling as his peers, and apologizes for the mistake, namely that the puzzle was way too difficult.

To measure cortisol reactivity five cortisol samples were collected from participants during this test. The first sample was taken upon arrival to the testing room before starting the executive function tests. A second sample was taken immediately after the stress test. Afterwards, children were taken to a separate room where they could sit and colour or play until all subsequent saliva samples were collected. The following three samples (after 15-15 minutes) were taken in that room. The area under the curve (AUC) during the stress test was calculated by the trapezoid formula presented by Pruessner and colleagues (2013). There are two types of data that can be computed: the area under the curve with respect to ground (AUCg) and the area under the curve with respect to increase (AUCi). The AUCg refers is informative regarding the overall cortisol production during the sampling procedure, while the AUCi contains information about the change as compared to the baseline during the procedure.

Three participants received the TSST test in the afternoon. As cortisol values and patterns can be very different before and after noon because of the diurnal rhythm of the cortisol production of the human body, data of these participants was excluded from the analyses regarding cortisol reactivity.

Short-term and working memory. For measuring short-term memory and working memory, digit span forward and backward tests were used, respectively (Wechsler, 2003). The items were recorded and played on a laptop in order for a standardized presentation. There were two practice items before both the forward and backward parts including two digits per item. On every level there were two items, but the number of the digits increased by one on each level. The test was finished in case the child made a mistake on both items. For every correct item the child received one point.

Inhibition and cognitive flexibility. We used a modified version of the fish and shark Go/No-Go task (Wiebe et al., 2012) in which the participant is asked to press a button for the go stimulus but not to press for the no-go stimulus. We used pictures of animals as stimuli (cat and tiger on the pre-test, fish and shark on the post-test). Each stimulus was presented for 1500 ms unless the participant responded by pressing a button. Before starting the task six practice trials were presented. After this first block, we switched the rule so that children were asked not to respond to the go stimulus of the first block (e.g., the fish) and press the button for the no-go stimulus of the first block (e.g., the shark). In the third block, the rules changed back to the rules of the first block. These rule switching blocks were included as an attempt to assess cognitive flexibility. Thus, commission errors were calculated for the first block and considered as a measure of inhibitory control and the sum of the commission errors in the second and third block was taken as an indicator of cognitive flexibility. Each block consisted of 16 go and 8 no-go trials. The test was run on PsychoPy 1.85.1 version (Peirce, 2007).

However, results of this task showed floor effect (Commission errors at pre-test in the intervention group were: M_{block1} = 0.15 (SD = 0.37), M_{block2} = 0.42 (SD = 0.58), M_{block3} = 0.77 (SD = 0.81) and in the control group were: M_{block1} = 0.60 (SD = 1.63), M_{block2} = 0.80 (SD = 1.70), M_{block3} = 0.64 (SD = 1.15) and the change scores from pre- to post-test in the intervention group were: M_{block1} = -0.74 (SD = 1.05), M_{block2} = -0.21 (SD = 0.92), M_{block3} = -0.32 (SD = 1.25) and in the control group were: M_{block1}:= 0.00 (SD = 1.00), M_{block2} = -0.38 (SD = 0.87), M_{block3} = -0.15 (SD = 1.07) thus we did not conduct analyses on these variables.

Cognitive flexibility. The Dimensional Change Card Sort (DCCS) task (Zelazo, 2006) was used to measure cognitive flexibility. We used green and yellow cars and flowers as the stimuli on the pre-test, while red and blue rabbits and boats were applied on the post-test. This task consists of two parts. The first part is the standard version in which the child is asked to sort cards based on one dimension: based on colour in the first block and based on shape in the second block. There were two practice trials followed by six test trials in the first block. After that the last six cards should be sorted based on shape (no practice trials). In the second part of the test, cards with the same stimuli are used except that half of the cards have a black border around and half of them do not. Children are asked to sort the cards according to colour or shape depending on whether the card has a border or not. In this second part there are two practice and 12 test trials. The number of correct trials on the third block was calculated.

Behavior problems. To assess behavior problems of the participating children the short Hungarian version of the Child Behaviour Checklist (Achenbach & Edelbrock, 1991 translated by Gádoros, 1996) was filled in by the parents before the intervention (pre-test in August) and one month after school entry (follow-up in October). This questionnaire consists of 46 items and there are six scales: Social Problems, Anxious/Depressed, Somatic Complaints, Attention Problems, Rule-Breaking Behavior, Aggressive Behavior.

From the total sample (n = 51) only parents of 16 children filled in the questionnaires at the pre-test and follow-up time points thus the results of these questionnaires could not be analysed.

4.3.7 Statistical analyses

We used the time of sampling during the day as a covariant in the cortisol analyses because there was quite some variation in when we could take samples in the morning or when we could start the stress induction test. ANOVAs were applied. The assumption of normal distribution was assessed by the standardized skewness and kurtosis values not exceeding +/-1.96 (Field, 2013).

4.4 Results

4.4.1 Cognitive skills

Pre-test differences. 17 children did not attend the post-test session thus the final sample for these analyses consisted of 34 participants. For testing any possible differences at pre-test, we ran a univariate ANOVA with the scores on each test as the dependent variable and condition and gender as fixed factors. We did not find any main effects of condition, gender or a condition x gender interaction on the digit span forward, the digit span backward or the DCCS tasks (for pre-test results see Table 8 and for statistic see Table 9).

Table 8.

Baseline (pre-test) values in the control and the intervention group on each outcome measures included at post-test or follow-up assessment.

Sampling included on testing	**Subgroups**															
	control		intervention		boy		girl		control				intervention			
									boy		girl		boy		girl	
	Mean (*SD*)	*n*	Mean (*SD*)	*n*	Mean (*SD*)	*n*	Mean (*SD*)	*n*	Mean (*SD*)	*n*	Mean (*SD*)	*n*	Mean (*SD*)	*n*	Mean (*SD*)	*n*
Cortisol [a]																
Pre-Post cortisol change	-0.009 (0.906)	13	-0.020 (1.078)	19	0.448 (1.021)	11	-0.259 (0.914)	21	0.015 (0.633)	5	-0.025 (1.084)	8	0.809 (1.191)	6	-0.402 (0.805)	13
Pre-September cortisol change	-0.023 (0.933)	21	0.024 (1.065)	20	0.273 (1.062)	18	-0.214 (0.891)	23	0.087 (0.831)	11	-0.144 (1.067)	10	0.564 (1.371)	7	-0.267 (0.770)	13
Pre-October cortisol change	-0.009 (0.938)	21	0.009 (1.058)	21	0.291 (1.070)	18	-0.218 (0.881)	24	0.102 (0.835)	11	-0.131 (1.072)	10	0.589 (1.384)	7	-0.281 (0.753)	14
Cognitive functions [b]																
Digit span forward	5.33 (1.23)	15	5.16 (1.50)	19	5.46 (1.85)	13	5.10 (1.00)	21	5.86 (1.46)	7	4.88 (0.84)	8	5.00 (2.28)	6	5.23 (1.09)	13
Digit span backward	2.73 (1.16)	15	2.42 (1.12)	19	2.77 (1.24)	13	2.43 (1.08)	21	2.57 (1.51)	7	2.88 (0.84)	8	3.00 (0.89)	6	2.15 (1.14)	13
DCCS	7.29 (1.98)	14	7.37 (2.11)	19	6.92 (1.44)	12	7.57 (2.29)	21	6.83 (1.17)	6	7.63 (2.45)	8	7.00 (1.79)	6	7.54 (2.30)	13

Note. [a] *Results are standardised cortisol values.* [b] *Achieved scores on each test. DCCS = Dimensional Change Card Sort.*

Table 9.

Group and gender differences at pre-test.

	condition				**gender**				**condition x gender**				**pre-test sampling time**			
	F	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2
Cortisol																
Pre-Post cortisol change	0.24	1,27	.63	.009	3.43	1,27	.08	.113	3.43	1,27	.08	.113	1.66	1,27	.21	.058
Pre-September cortisol change	0.38	1,36	.54	.010	2.63	1.36	.11	.068	1.05	1,36	.31	.028	0.27	1,36	.61	.007
Pre-October cortisol change	0.33	1,37	.57	.009	2.97	1,37	.09	.074	1.18	1,37	.28	.031	0.21	1,37	.65	.006
Cognitive functions																
Digit span forward	0.25	1,30	.62	.008	0.57	1,30	.46	.019	1.49	1,30	.23	.047	-	-	-	-
Digit span backward	0.13	1,30	.72	.004	0.45	1,30	.51	.015	2.03	1,30	.17	.063	-	-	-	-
DCCS	0.003	1,29	.96	.000	0.75	1,29	.39	.025	0.03	1,29	.87	.001	-	-	-	-

Note. DCCS = Dimensional Change Card Sort.

Short-term memory. To test the effect of the intervention on the digit span forward task, a repeated measures ANOVA was applied with time as the within-subjects factor (pre-test and post-test) and condition and gender as between-subjects factors. There was a significant main effect of time, children's short-term memory performance decreased in the whole group from pre-test (M = 5.24, SD = 1.37) to post-test (M = 4.79, SD = 1.27). There were no main effects of condition or gender, and no significant time x condition, time x gender or time x condition x gender interactions either (for descriptive statistics see Table 10 and for test statistics see Table 11).

Working memory. Again, a Repeated Measures ANOVA was applied with time as a within-subjects factor and condition and gender as between-subjects factors to test the effect of the intervention. There were no significant main effects of time, condition or gender, or significant time x condition, time x gender or time x condition x gender interactions (for descriptive statistics see Table 10 and for test statistics see Table 11).

Shifting skills. There was one outlier we had to exclude from the analysis thus the final sample consisted of 33 participants in the analysis regarding shifting skills. We used a repeated measures ANOVA again with time as a within-subjects factor and condition and gender as between-subjects factors to test the effect of the intervention. There were no significant main effects of time, condition or gender, and no significant time x condition, time x gender or time x condition x gender interactions (For descriptive statistics see Table 10 and for test statistics see Table 11).

Table 10.

DCCS and digit span scores of the participants (who participate both pre- and post-tests)

Test	**Pre-test**								**Post-test**							
	control				intervention				control				intervention			
	boy		girl		boy		girl		boy		girl		boy		girl	
	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*
Digit span forward	5.86 (1.46)	7	4.88 (0.84)	8	5.00 (2.28)	6	5.23 (1.09)	13	5.14 (1.57)	7	4.63 (1.30)	8	4.17 (1.17)	6	5.00 (1.15)	13
Digit span backward	2.57 (1.51)	7	2.88 (0.84)	8	3.00 (0.89)	6	2.15 (1.14)	13	2.71 (0.49)	7	2.50 (2.00)	8	2.83 (0.75)	6	2.08 (1.12)	13
DCCS	6.83 (1.17)	6	7.63 (2.45)	8	7.00 (1.79)	6	7.57 (2.93)	13	6.50 (1.23)	6	7.88 (3.14)	8	7.17 (2.23)	6	7.85 (2.97)	13

Note. DCCS = Dimensional Change Card Sort

Table 11.

Effects of the intervention on short-term memory, working memory and shifting skills

	time				condition				gender				time x condition				time x gender				time x condition x gender			
	F	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2
Digit span forward	6.02	1, 30	.02	.167	0.41	1,30	.53	.013	0.06	1,30	.80	.002	0.02	1, 30	.91	.000	1.67	1, 30	.21	.053	0.03	1, 30	.87	.001
Digit span backward	0.26	1, 30	.61	.009	0.25	1,30	.62	.008	1.59	1,30	.22	.050	0.00	1, 30	.99	.000	0.21	1, 30	.65	.007	0.43	1, 30	.52	.014
DCCS	0.07	1, 29	.80	.002	0.05	1,29	.82	.002	1.14	1,29	.29	.038	0.13	1, 29	.72	.005	0.23	1, 29	.64	.008	0.08	1, 29	.77	.003

Note. DCCS = Dimensional Change Card Sort

4.4.2 Baseline cortisol levels

Pre-test differences. From the total sample (n = 51) for two children we did not succeed to collect sufficient amount of saliva on the pre-test thus they were excluded from all baseline cortisol analyses and further 16 children were missing from preschool during the post-test week. In case of one participant the elementary school refused to participate so they had to be excluded from analyses including follow-up assessment of cortisol. During data collection in September the volume of saliva of another seven children was insufficient. Regarding the cortisol data in October, one child dropped out of the study and the volume of saliva of five children was insufficient. For the reasons for missing data see Figure 7.

Because of the two-wave data collection (the summers of 2017 and 2018) we checked if there were any differences between the two years' cortisol results. Significantly higher cortisol concentrations were measured at pre-test in 2018 (M = 0.106, SD = 0.047; n = 22) than in 2017 (M = 0.068, SD = 0.036; n = 27); $t(47)$ = -3.24 p = .002, which is most likely due to measurement error . Because of this difference we standardised the change in cortisol values from pre-test to post-test/follow-up in the two years and used these variables as the dependent variables in the ANOVAs.

In order to investigate the differences in standardised cortisol values at pre-test we ran univariate ANCOVAs in each subsample (participants included on the change from pre- to post-test, from pre-test to September and from pre-test to October cortisol analyses). We used standardised pre-test cortisol values as the dependent variable, condition and gender as fixed factors and the time of sampling as a covariant.

Regarding data of the participants with pre- and post-test cortisol data (n = 32), there were no effects of condition or sampling time but there was a marginally significant main effect of gender and a marginally significant condition x gender interaction, as shown in Table 8. The main effect of gender suggested that boys had higher cortisol levels. The interaction effect suggests that the gender difference was detectable only in the intervention group ($F(1,16)$ = 7.69, p = .01, η^2 = .325) but not in the control group (F (1,11) = 0.01, p = .94, η^2 = .001). These possible differences were also tested in case of those participants who could be included into the analyses regarding the follow-up assessment. In case of those participants who were included in the pre-test to September cortisol analysis there was no effect of condition, gender or sampling time and no significant interaction between condition and gender. Similarly, we tested these effects in the subsample included in the pre-test to October analysis. In this group there was also no effect of condition or sampling time and no significant condition x gender interaction. However, there was a marginally significant effect of gender showing that boys had higher cortisol levels in this subsample too. (for the descriptive statistics see Table 8 and the test results see Table 9.)

The effects of the intervention. A univariate ANCOVA was applied to test the effects of condition on children's change in baseline cortisol levels from pre- to post-test with the standardized change in cortisol levels from pre- to post-test as a dependent variable, condition and gender as fixed factors and the two sampling times as covariates. One outlier had to be excluded for normal distribution. Levene's test indicated unequal error variances (F (3,28) = 3.15, p = .04). There were no effects of condition, pre- or post-test sampling times, or a significant condition x gender interaction, but there was a marginally significant effect of gender. Boys' cortisol levels decreased from pre- to post-test (M = -0.440, SD = 0.966), while girls' cortisol levels increased (M = 0.134, SD = 0.866) (for the descriptive statistics and the test results see Table 12.)

To test the effect of the intervention after school entry, again, we conducted a univariate ANCOVA with the standardised change scores in cortisol values from the pre-test in August to the first week of school in September as the dependent variable, condition and gender as fixed factors and the pre-test and follow-up sampling times as covariates. There was no main effect of the sampling time at the pre-test but a marginally significant main effect of the follow-up sampling time. There was no main effect of either condition or gender, but there was a significant condition x gender interaction (for the descriptive statistics and the test results see Table 12).

In order to investigate the condition x gender interaction, we ran univariate ANCOVAs for boys and girls separately. We used standardised change scores in cortisol as the dependent variable and condition as a fixed factor. The two sampling times were used as covariates again. For the boys there was no main effect of either the pre-test sampling times (F(1,14) = 0.02, p = .897, η^2 = .001) or the follow-up sampling times (F(1,14) = 0.25, p = .625, η^2 = .018). The main effect of condition was found large, although it did not reach significance (F(1) = 2.62, p = .128, η^2 = .158). More specifically, boys' cortisol levels decreased in the intervention and not in the control group (for standardised change scores see Table 12 and Figure 9.) For the girls there was no main effect of the pre-test sampling times (F(1,19) = 0.17, p = .687, η^2 = .009) but there was a significant main effect of the follow-up sampling times (F(1,19) = 6.50. p = .020, η^2 = .255). The effect of the condition was small and not significant (F(1) = 0.29, p = .600, η^2 = .015) (for standardized change scores in each group see Table 12 and Figure 10.)

Figure 9.

Effects of the intervention (change scores and SD) on morning cortisol levels from pre-test to September in boys.

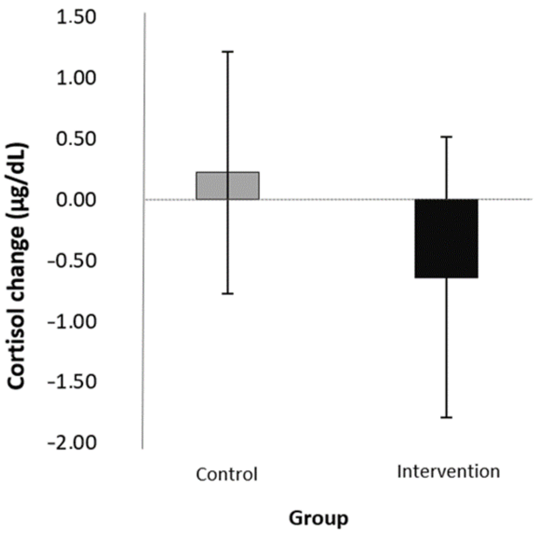
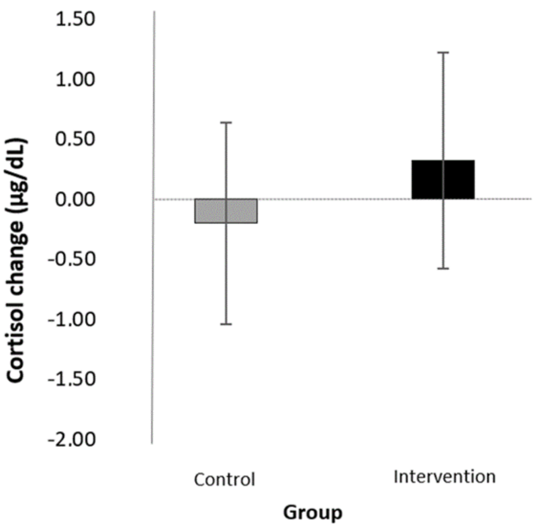


Figure 10.

Effects of the intervention (change scores and SD) on morning cortisol levels from pre-test to September in girls.



In case of the second follow-up measure (the change from August to October), again, we used standardised change scores in cortisol values as the dependent variable, condition and gender as fixed factors and the pre-test and follow-up sampling times as covariates in the univariate ANCOVA. There were no main effects of either the pre-test cortisol sampling time, the follow-up cortisol sampling time, condition or gender. Also, there was no condition x gender interaction (for standardized change scores in each group and statistic see Table 12).

4.4.3 Cortisol reactivity

To test the effect of the intervention on children' cortisol reactivity we ran a univariate ANCOVA with the standardized scores of the AUCg during the stress test as the dependent variable, condition and gender as fixed factors and the time of the first cortisol sample as a covariate. There were no significant main effects of sampling time, condition or gender on total cortisol production (AUCg). Also, there was no significant condition x gender interaction (for standardized cortisol values and statistic see table 13).

To test the change in cortisol (AUCi) during the stress test we had to exclude a soft outlier from the dataset to fulfil the assumption of normal distribution. We used the same model presented above despite Levene's test of equality of error variances was significant (F =3.11, p = .045). There were no effects of condition, gender, or the sampling time and no significant condition x gender interaction (for standardized cortisol values and statistic see Table 13.)

Table 12.

Effects of the intervention on cortisol levels

Measurement	**Standardized change scores**								**Univariate ANCOVA**																			
	control				intervention				pre-test sampling time				post/follow-up sampling time				condition				gender				condition x gender			
	boy		girl		boy		girl																					
	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2
Pre-test-Post test	-0.44 (0.20)	5	0.40 (1.19)	8	-0.44 (1.36)	6	-0.03 (0.59)	13	1.42	1,26	.24	.052	0.004	1,26	.95	.000	0.28	1,26	.60	.011	3.17	1,26	.09	.109	0.15	1,26	.70	.006
August-September	0.22 (0.99)	11	-0.20 (0.84)	10	-0.64 (1.15)	7	0.32 (0.90)	13	0.10	1,35	.75	.003	3.31	1,35	.08	.086	1.31	1,35	.26	.036	1.14	1,35	.29	.032	5.43	1,35	.026	.134
August-October	0.23 (0.96)	11	-0.054 (0.95)	10	-0.53 (1.15)	7	0.12 (0.95)	14	1.23	1,36	.27	.033	2.68	1,36	.11	.069	1.85	1,36	.18	.049	1.00	1,36	.32	.027	2.47	1,36	.125	.064

Table 13.

Effects of the intervention on stress induced cortisol responses

Measu-rement	**Standardised cortisol values**								**Univariate ANCOVA**															
	control				intervention				sampling time				condition				gender				condition x gender			
	boy		girl		boy		girl																	
	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	F	*df*	*p*	η^2
AUCg	0.30 (0.86)	7	-0.14 (1.45)	7	0.057 (0.68)	6	-0.16 (0.90)	9	1.37	1, 24	.25	.054	0.066	1, 24	.80	.003	0.58	1, 24	.45	.024	0.03	1, 24	.86	.001
AUCi	0.31 (0.96)	7	-0.12 (0.41)	6	-0.01 (0.56	6	-0.39 (1.26	9	0.31	1,23	.58	.013	0.73	1,23	.40	.031	1.32	1,23	.26	.054	.01	1,23	.910	.001

Note: means = standardized cortisol values, AUCg = Area Under the Curve with respect to ground, AUCi = Area Under the Curve with respect to increase

5. Study 3

Benefits of a mindfulness-based intervention upon school entry on executive functions and behavioral problems.

5.1 Aim of the study

In order to test whether the benefits of mindfulness on children's executive function skills are at least partly due to reduction in their stress levels, in the previous experiment (Study 2) we tested the effects of a short one-week long mindfulness-based intervention applied with pre-schoolers before school entry on executive function skills and salivary cortisol when starting school (Koncz et al., 2022). In that experiment the intervention we applied was only 5-session long and it was quite an intense program: all sessions were held within a week. However, the intervention prevented a rise in boys' cortisol levels after school entry compared to the control group, we did not find any effects on executive function skills. In the present experiment we aimed to test the effects of a similar but slightly longer mindfulness-based program: we extended the intervention by one session to explain what stress is and why stress management is important to put the intervention in context. Additionally, in the present study we applied the intervention right upon school entry for maximal temporal contiguity.

5.2 Hypotheses

H8: A mindfulness program after school entry can reduce children's morning cortisol levels in this stressful life situation (Koncz et al., 2022).

H9: Children's executive function skills, would be improved (Moore & Malinowski, 2009; Takacs & Kassai, 2019).

H10: There would be improvements in children's behavior problems and prosocial behavior as a result of the intervention (Cheang et al., 2019).

5.3 Methods

5.3.1 Study approval

The study was approved by the Research Ethics Committee of the Faculty of Education and Psychology at Eötvös Loránd University under the registration number 2019/249.

5.3.2 Participants

First-graders from four classes of a state primary school from an average-SES district in Budapest (Hungary) were recruited. 63 parents agreed to participate with their children. Participants with no mental or somatic disorders that could influence children's cortisol levels were eligible. Two children had to be excluded from the experiment: one because he was a twin sibling of a participant, and another one who was missing from school during the pre-tests. Thus, the final sample consisted of 61 children (38 boys and 23 girls). Additionally, three participants did not have data on the executive function tests because they were missing from school due to illness during the post-test. For a detailed account of the number of participants whose data could be used for the different analyses see Figure 11. The mean age of the participants was 84.95 months (*SD* = 5.21) ranging between 73 and 96 months.

5.3.3 Design

It was a randomised controlled trial with a between-subjects design. First-graders from four classes of a primary school (11, 15, 17 and 18 children) participated. Participants from each class were matched based on gender, age and pre-test executive function scores, and randomly assigned to either the experimental or passive control group. Evidently, there was no difference in children's age ($t(59) = 0.61$, $p = .543$) or gender distribution ($X^2(1, N = 91) = 0.13$, $p = .716$) between the experimental and the control group (for descriptive statistics see table 14). The pre-test was implemented on the week before (second week of September) and the post-test on the week after the intervention (third week of October), while a follow-up measurement of salivary cortisol levels was implemented one month after the post-test, that is, on the second week of November.

Table 14.

Descriptive statistics of the participants in the control and intervention groups who included in at least one of the analyses.

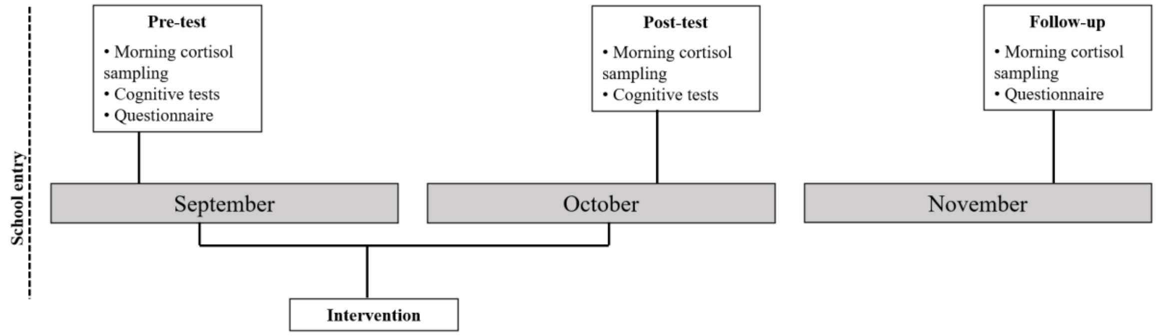
	Intervention		Control	
	n	age months Mean (*SD*)	*n*	age months Mean (*SD*)
boy	20	85.85 (5.41)	18	82.28 (5.76)
girl	11	84.45 (3.88)	12	83.42 (5.30)
total	31	85.35 (4.90)	30	84.53 (5.56)

5.3.4 Procedure

Children were taken from the classroom to an empty room in the school for an individual testing session with executive function tests on the pre- and post-test weeks between 8:00 AM and 2:00 PM. Morning cortisol samples were collected on two consecutive days between Tuesdays and Thursdays upon arrival to school from 7:45 AM to 8:00 AM on each measurement points (pre-test, post-test and follow-up). Cortisol sampling was timed to mid-week to avoid any differences due to the very first or very last day of the school week.

Figure 11.

Timeline of the experiment

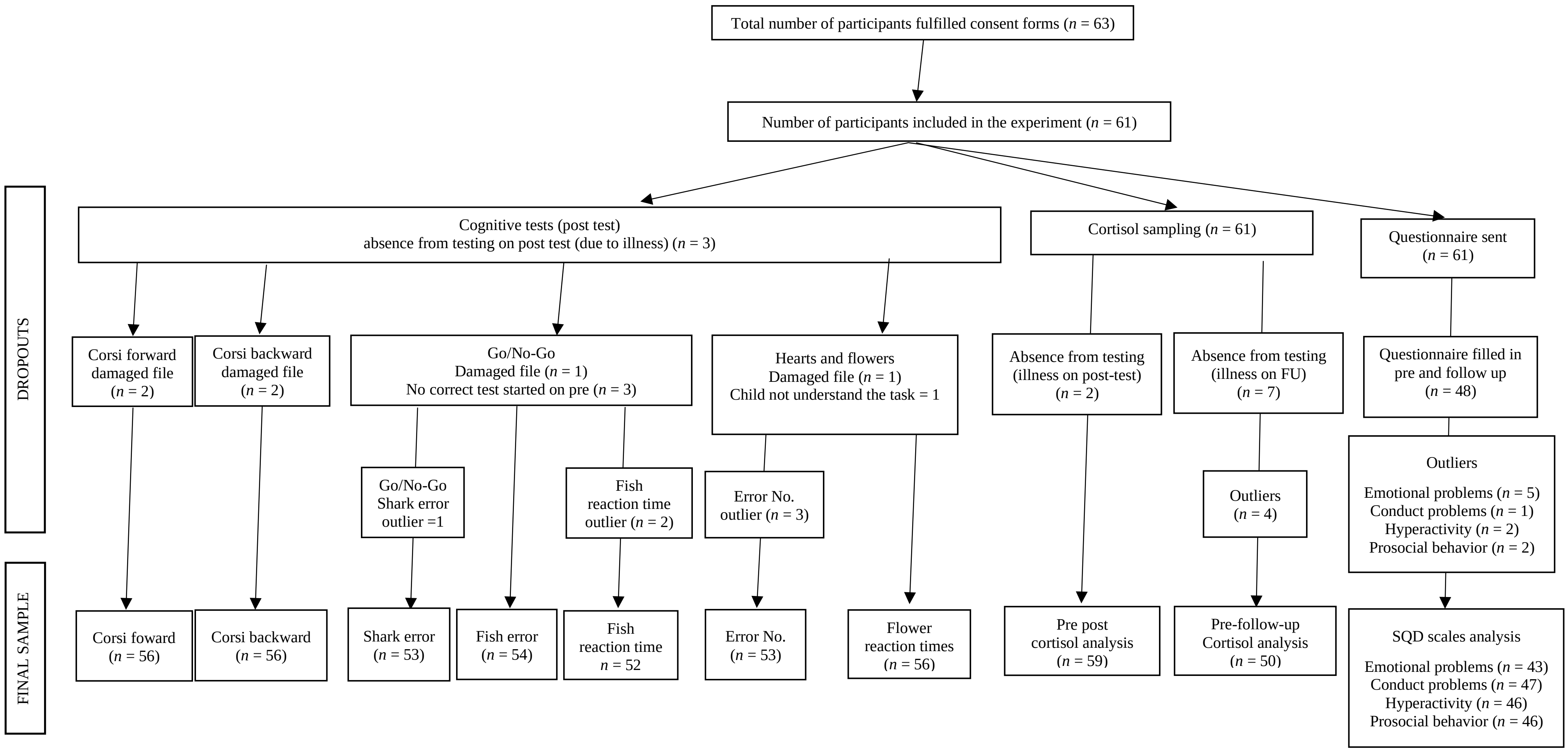


While participants started the first grade on the 2nd of September, the mindfulness program for the experimental group started on the third week of September. The program consisted of six sessions of 45 minutes, applied twice a week. Every session was conducted with the experimental group of each class in groups of 6-9 children in their own classroom. Thus, there were four mindfulness groups altogether. Trained research assistants led the sessions. During this time the control group had free play in the schoolyard. (For the timeline of the experiment see Figure 11.)

Executive function tests were implemented on an individual session in the school in designated rooms. All executive function tests were performed on a computer and results were recorded by PsychoPy (ver. 1.85.1) (Peirce, 2007). At the beginning of the testing session each child received a certificate with his/her name on it and children earned stickers when they completed a test for the purpose of motivation.

Figure 12.

Number of participants whose data could be analysed in each analysis



5.3.5 Intervention materials

The mindfulness group attended a six-session-long, story-based mindfulness training over three weeks. A modified and expanded version of the previously used program was applied (see Study 2 and Appendix 4). The first session was a modified version of a lesson for children about stress symptoms and opportunities for stress reduction developed by a Hungarian foundation (Lélekkel az egészségért). The following five sessions were based on the previously used program (Appendix 4.). It incorporates mindfulness practices in the storyline that are practiced together with the characters. Another modification for the present study was that we supplemented the program with short questions to the children at the beginning of the sessions about what they had learned in the previous session and a discussion at the end of the session for a short summary.

5 3.6 Measurement instruments

Baseline cortisol levels. As in Study 2 saliva samples were collected with sponge-ended samplers and stored at -20 °C in Eppendorf tubes until laboratory assessment. Cortisol concentrations (*µg/dL*) were determined with the method of enzyme-linked immunosorbent assay (ELISA) and the same plate was used to measure all samples of a participant in order to avoid errors caused by interassay variation. Two samples were taken at each measurement point and the mean of the two values were used in the statistical analyses.

Corsi forward and backward. For measuring children's short-term and working memory capacity, a computerised version of the Corsi block tapping test was used (Corsi, 1972). During the test nine squares appear at different parts of on the screen at a random order. Participants are asked to recall the order either forward or backward. The test starts with two squares flashing as the first level with one more additional square on each level. On each level there are two items. First, participants are asked to point to the squares that flashed in the same order. This forward version of the test measures short-term memory. After an incorrect answer the test goes back to the previous level and provides two trials on that level. After three errors the test finishes, regardless if it was three consecutive errors or there were correct trials in between. In the backward version of the test, which measures working memory capacity, the same procedure was followed except that the child had to point to the squares in reverse order. In both parts of the test, the child got as many points as the number of squares on the highest level they achieved.

Go/No-Go task. A Go/No-Go task was used to measure inhibitory control and sustained attention. In this task the child had to press a button if a fish appeared on the screen (go stimulus) but avoid pressing the button if a shark appeared (no-go stimulus) (Wiebe et al., 2012). Stimuli were presented for 500 ms and the interstimuli intervals were 1200 ms. There were six practice trials after which the child received feedback for their answer. Afterwards, there were 99 trials, two-thirds of which presented the go stimuli and one-third included the no-go stimulus. Three scores were computed: the number of errors on the no-go trials (commission error) measuring inhibitory control, the number of errors on the go trials (omission error) and the mean reaction time on correct go trials both measuring sustained attention.

Hearts and Flowers task. The Hearts and Flowers task (Brocki & Tillman, 2014) was used to assess cognitive flexibility. This test consists of three blocks. First, hearts appear on one side of the screen and the participants are to press a button on that side (congruent condition). In the second block flowers appear on one side of the screen and children are asked to press the button on the opposite side (incongruent condition). Finally, hearts and flowers both appear in the third block and the task is to follow the previously learnt rules: pressing a button on the same side when hearts are presented and on the opposite side when flowers appear (mixed condition). This final block measures cognitive flexibility. There were four-four practice trials at the beginning of the congruent and incongruent blocks and eight practice trials at the beginning of the mixed block, for which the child received feedback. Each block consisted of 40 trials. Stimuli were presented for 1500 ms with 500 ms long interstimuli interval. Two scores were calculated from the mixed block: the number of errors and the mean reaction time on correct trials.

Strengths and Difficulties Questionnaire. The Hungarian parent version of the Strengths and Difficulties Questionnaire (Goodman, 1997) was sent to the parents of the participants before the intervention and on follow-up (one month after the post-test session). This questionnaire is a valid measurement instrument of behavior problems (Turi et al., 2013). Parents were asked to complete a questionnaire about their child regarding the previous month. This questionnaire consists of 25 items. Five scales are computed: emotional problems (Cronbach's alphas: .57 at pretest and .66 at posttest), conduct problems (Cronbach's alphas: .64 at pretest and .59 at posttest), hyperactivity (Cronbach's alphas: .74 at pretest and .76 at posttest), peer problems (Cronbach's alphas: .58 at pretest and .23 at posttest) and prosocial behavior (Cronbach's alphas: .70 at pretest and .70 at posttest). Each scale consists of five items. Based on the recommendation of Pallant (2013) which suggests that in case of 10 or fewer items, the Cronbach's alpha should be above .05. Therefore results from the peer problems subscale were not analysed.

5.3.7 Statistical analyses

First in order to test possible baseline (pre-test) differences on the outcome measures, we ran univariate ANOVAs with the pre-test scores on each outcome measure as the dependent variable and condition and gender as fixed factors. We included the data of those children in these baseline analyses who also had data on the post-test/follow-up and were thus also included in those analyses. Additionally, if a participant was an outlier only on the pre-test results we excluded him/her only from these baseline analyses. In case the assumptions of the univariate ANOVA were not met, even after excluding the mentioned outliers, as a first step, the square root transformation was performed. If the assumptions were still not met, the non-parametric Mann-Whitney U-test was performed on the original sample.

Then repeated measures ANOVAs were applied for each outcome variable to test the effects of the intervention. We used time (pre- to post-test / follow-up) as a within-subjects factor and condition and gender as between-subject factors. Standardized skewness and kurtosis values not exceeding +/-3.29 were considered to reflect normal distribution (Field, 2013). After excluding outliers, assumptions of the analyses were always met.

5.4 Results

5.4.1 Corsi test

One participant had to be excluded from these analyses because their output file was damaged.

Short-term memory.

One additional participant had to be excluded from these analyses because their output file was damaged on the forward task. Regarding the pre-test differences, we used a series of Mann–Whitney U-tests. As shown in Table 15, no significant effects were found on the pre-test scores.

Table 15 .

Results of Mann-Whitney U-tests of pre-test data

	Intervention	Control	Boy	Girl	Intervention		Control	
					Boy	Girl	Boy	Girl
Corsi forward								
Median	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Test results	*U* = 389.00, *p* = .975		*U* = 282.00, *p* = .162		*U* = 66.00, *p* = .274		*U* = 72.00, *p* = .451	
SDQ Emotional problems								
Median	1.00	1.00	1.50	1.00	2.00	1.00	1.00	1.00
Test results	*U* = 392.00, *p* = .510		*U* = 205.50, *p* = .568		*U* = 57.50, *p* = .558		*U* = 44.50, *p* = .968	

In regard to the effect of the intervention, as shown in Table 16, there was no main effects of condition, time or gender or any interaction between those on the Corsi forward test results (for descriptive statistics see Table 17).

Table 16.

Effects of the intervention on short-term memory, working memory and shifting skills and cortisol levels

Measurement	Repeated-measures ANOVA																											
	time				condition				gender				condition x gender				time x condition				time x gender				time x condition x gender			
	F	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2
Corsi																												
Forward	0.99	1,52	.325	.019	0.64	1,52	.428	.012	2.17	1,52	.147	.040	0.04	1,52	.840	.001	1.05	1,52	.232	.027	0.33	1,52	.570	.006	0.29	1,52	.593	.006
Backward	9.87	1,52	.003	.160	0.02	1,52	.886	<.001	1.82	1,52	.182	.020	1.04	1,52	.312	.020	4.28	1,52	.044	.076	0.46	0,52	.500	.009	7.63	1,52	.008	.128
Go/No-Go																												
Shark error	2.74	1,49	.104	.053	1.08	1,49	.305	.021	0.21	1,49	.648	.005	0.05	1,49	.824	.001	4.75	1,49	.034	.088	0.12	1,49	.374	.002	3.77	1,49	.058	.071
Fish error	3.16	1,50	.081	.059	0.000	1,50	.998	<.001	0.24	1,50	.629	.005	0.001	1,50	.969	<.001	0.42	1,50	.519	.008	0.05	1,50	.834	.001	2.19	1,50	.145	.042
Fish rt	0.77	1,48	.384	.016	0.64	1,48	.429	.013	1.67	1,48	.203	0.34	0.14	1,48	.714	.003	0.20	1,48	.661	.004	0.001	1,48	.970	<.001	0.87	1,48	.355	.018
Hearts and flowers																												
Errors	9.21	1,49	.004	.158	1.01	1,49	.319	.020	0.48	1,49	.491	.010	0.08	1,49	.780	.002	3.03	1,49	.088	.058	0.70	1,49	.408	.014	0.38	1,49	.538	.008
Rt.	3.62	1,52	.063	.065	0.22	1,52	.639	.004	0.40	1,52	.529	.004	0.19	1,52	.663	.004	0.52	1,52	.473	.010	0.10	1,52	.755	.002	0.11	1,52	.740	.002

Note Rt = reaction time

Table 17.

Performance on cognitive tests and cortisol levels before and after the intervention

Name of the outcome	**Pre-test**								**Post-test / follow-up**							
	intervention				control				intervention				control			
	boy		girl		boy		girl		boy		girl		boy		girl	
	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*
Corsi																
Forward	3.75 (1.16)	20	4.33 (0.87)	9	3.87 (1.26)	16	4.18 (0.75)	11	3.90 (1.02)	20	4.11 (0.60)	9	4.25 (1.07)	16	4.55 (1.04)	11
Backward	3.20 (1.24)	20	2.90 (1.60)	10	2.80 (1.52)	15	4.18 (1.27)	11	3.80 (1.06)	20	4.30 (0.66)	10	3.67 (1.59)	15	3.73 (0.91)	11
Go/No-Go																
Shark (omission) error	6.85 (4.68)	20	5.14 (2.91)	7	7.88 (3.70)	16	9.00 (4.80)	10	6.20 (4.18)	20	6.43 (3.16)	7	6.94 (4.67)	16	5.30 (4.17)	10
Fish (commission) error	44.60 (8.19)	20	45.13 (8.11)	8	45.69 (6.58)	16	42.20 (11.00)	10	42.95 (8.72)	20	39.88 (10.64)	8	41.69 (12.47)	16	43.00 (12.26)	10
Fish reaction time (s)	0.388 (0.024)	18	0.392 (0.040)	8	0.377 (0.036)	16	0.394 (0.024)	10	0.390 (0.027)	18	0.400 (0.036)	8	0.383 (0.035)	16	0.391 (0.017)	10
Hearts and flowers																
Error	11.55 (6.83)	20	10.60 (8.10)	10	9.36 (7.66)	14	6.44 (6.06)	9	8.05 (6.47)	20	7.40 (7.04)	10	7.43 (7.81)	14	6.56 (7.52)	9
Reaction time (s)	1.189 (0.345)	20	1.106 (0.462)	10	1.213 (0.361)	16	1.234 (0.326)	10	1.124 (0.356)	20	1.024 (0.284)	10	1.105 (0.278)	16	1.055 (0.223)	10
Cortisol																
Pre-test-post-test (μg/dL)	0.173 (0.112)	20	0.151 (0.087)	10	0.160 (0.138)	17	0.139 (0.113)	12	0.190 (0112)	20	0.216 (0.118)	10	0.184 (0.160)	17	0.126 (0.122)	12
Pre-test-Follow-up (μg/dL)	0.155 (0.094)	18	0.146 (0.096)	8	0.180 (0.144)	14	0.161 (0.112)	10	0.164 (0.083)	18	0.156 (0.096)	8	0.147 (0.132)	14	0.171 (0.131)	10

Working memory.

One additional participant had to be excluded from these analyses because his/her output files were damaged on corsi backward task. Two participants' data had to be excluded on the analyses of the pre-test data because their results were outliers. As shown in Table 18, only the effect of gender was significant on the pre-test scores showing that girls (*M* = 3.95, *SD* = 1.18) had higher scores than boys (*M* = 3.03, *SD* = 1.36) on the pre-test (for further descriptive statistics see Table 17).

Table 18.

Group and gender differences at pre-test on executive function skills and behavior problems

Sampling included on:	Univariate ANOVA											
	condition				gender				condition x gender			
	F	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2
Corsi												
Backward	0.04	1,50	.836	.001	5.77	1,50	.020	.103	1.62	1,50	.209	.031
Go/No-Go												
Shark (omission) error	3.99	1,49	.051	.075	0.06	1,49	.813	.001	1.34	1,49	.252	.027
Fish (commission) error	0.14	1,50	.706	.003	0.37	1,50	.543	.007	0.69	1,50	.411	.014
Fish reaction time	0.23	1,48	.637	.005	1.27	1,48	.256	.026	0.58	1,48	.450	.012
Hearts and flowers												
Mix error	2.40	1,49	.127	.047	0.68	1,49	.412	.014	0.12	1,49	.726	.003
Reaction time	0.54	1,52	.466	.010	0.09	1,52	.762	.002	0.25	1,52	.617	.005
Cortisol												
Pre-test-post-test	0.32	1,53	.574	.006	0.11	1,53	.918	<.001	0.02	1,53	.884	<.001
Pre-test-Follow-up	0.35	1,46	.557	.008	0.16	1,46	.687	.004	0.02	1,46	.881	<.001
SDQ scales												
Conduct problems	1.58	1,41	.215	.037	8.32	1,41	.006	.169	0.60	1,41	.445	.014
Hyperactivity	1.62	1,42	.211	.037	4.30	1,42	.044	.093	0.002	1,42	.962	<.001
Prosocial behavior	0.92	1,42	.342	.021	0.57	1,42	.455	.013	0.01	1,42	.946	<.001

Regarding the effects of the intervention, as shown in Table 6, there were no significant main effects of condition or gender on working memory, but there was a significant main effect of time showing that the average score increased from pre-test (*M* = 3.23, *SD* = 1.48) to post-test (*M* = 3.84, *SD* = 1.14). No significant condition x gender or time x gender interaction were detected but there were significant time x condition and time x condition x gender interactions.

To disentangle the time x condition x gender interaction effect, we ran repeated measures ANOVAs with time as a within-subjects factor and condition as a between-subjects factor, separately for boys and girls. For the boys there was a significant main effect of time

(F(1,33) = 9.73, p = .004, η^2 = .228): scores increased from pre-test to post-test regardless of the condition (for descriptive statistics see Table 17). There was no significant main effect of condition (F(1,33) = 0.46, p = .501, η^2 = .014) or a time x condition interaction (F(1,33) = 0.32, p = .574, η^2 = .010). For girls there was no significant main effects of time (F(1,19) = 2.40, p = .138, η^2 = .112) or condition (F(1,19) = 0.65, p = .429, η^2 = .033) but there was a significant time x condition interaction (F1,19) = 9.22, p = .007, η^2 = .327). More specifically, the scores of the girls in the intervention condition increased significantly (F(1,9) = 7.86, p = .021, η^2 = .467), while the scores of the girls in the control condition did not change (F(1,10) = 1.54, p = .242, η^2 = .134) (for descriptive statistics see Table 17).

5.4.2 Go No/Go task.

One output file was damaged thus one child was excluded from the results of all outcomes of the Go/No-Go task.

Inhibitory control. An additional participant was excluded from the analyses of the commission errors because it was an outlier on the change from pre- to post-test. Regarding the pre-test results, as shown in Table 18, a marginally significant effect of condition was found: the control group had a significantly higher number of errors (M = 8.31, SD =3.81) than the intervention group (M = 6.41, SD = 4.31). No significant main effect of gender or interaction between condition x gender were found (for descriptive statistic see Table 17).

When testing the effects of the intervention there were no main effects of time, condition or gender, and no condition x gender or time x gender interactions. However, as shown in Table 16, there was a significant time x condition interaction: errors in the intervention did not change significantly from pre-test (M = 6.41, SD = 4.31) to post-test (M = 6.26, SD = 3.88), while the number of errors in the control decreased significantly F(1,24) = 9.05, p = .006, η^2 = .274) from pre-test (M = 8.31, SD = 3.81) to post-test (M = 6.31, SD = 4.47). Also, there was a marginally significant time x condition x gender interaction. To reveal this interaction, we ran repeated measures ANOVAs separately for the two genders. For boys there were no significant main effects of time (F(1,34) = 1.16, p = .289, η^2 = .033) or condition (F(1,34) = 0.49, p = .487, η^2 = .014), and no time x condition interaction (F(1,34) = 0.04, p = .846, η^2 = .001). For girls, however, while there were no significant main effects of time (F(1,15) = 2.38, p = .144, η^2 = .137) or condition (F(1,15) = 0.67, p = .424, η^2 = .043), there was a significant time x condition interaction (F(1,15) = 10.13, p = .006, η^2 = .403) (for descriptive statistic see Table 3). More specifically, the number of errors girls in the intervention condition made did not significantly change from pre- to post-test ($F(1,6) = 10.13$, $p = .122$, $\eta^2 = .351$), however, the errors girls made in the control condition did decrease ($F(1,9) = 9.47$, $p = .013$, $\eta^2 = .513$) (for descriptive statistic see Table 17).

Sustained attention. In regard to the number of omission errors at pre-test, shown in Table 18, there were no significant main effects of condition, gender or a condition x gender interaction (for descriptive statistic see Table 17). When testing the effect of the intervention, shown in Table 16, we found a marginally significant effect of time: the number of errors slightly decreased from the pre-test ($M = 44.56$, $SD = 8.19$) to post-test ($M = 42.13$, $SD = 10.63$). There were no condition or gender main effects and no condition x gender, time x condition, time x gender or time x condition x gender interactions (for descriptive statistic see Table 17).

Regarding reaction times on correct go trials, two outliers had to be excluded from the analyses because they were outliers on the change they made from pre- to post-test. As shown in Table 18, on the pre-test there were no significant main effects of condition, gender or a condition x gender interaction (for descriptive statistic see Table 17). When testing the effects of intervention (shown in Table 16), there were no significant main effects (time, condition or gender) and no interaction effects (condition x gender, time x condition, time x gender, time x condition x gender) on the reaction time data.

5.4.3 Hearts and Flowers task.

One child was excluded due to damaged output file and another child because they did not understand the rules of the Hearts and Flowers task.

Cognitive flexibility. Regarding the change in the number of errors from pre- to post-test, three outliers were excluded. To analyse pre-test differences, the square root transformation was performed to meet the assumptions of the univariate ANOVA. As shown in Table 18, no significant main effects or interaction were detected.

When testing the effect of intervention, as shown in Table 2, time had a significant main effect: the number of errors decreased from pre-test ($M = 9.92$, $SD = 7.21$) to post-test ($M = 7.51$, $SD = 6.94$). There were no main effects of condition or gender and no interactions between condition x gender, time x gender or time x condition x gender. However, there was a marginally significant time x condition interaction.

In order to disentangle this interaction, the effect of time was tested separately in the two conditions. Repeated measures ANOVAs with time as a within-subjects factor and gender as a between-subjects factor were run for the two groups. A significant effect of time was found in the intervention group ($F(1,28) = 8.23$, $p = .008$, $\eta^2 = .227$) showing that the number of errors decreased from pre-test (M = 11.55, SD = 6.83) to post-test (M = 7.83, SD = 6.55). No significant gender main effect ($F(1,28) = 8.53$, $p = .745$, $\eta^2 = .004$) or time x gender interaction ($F(1,28) = 0.02$, $p = .899$, $\eta^2 = .001$) were found in the intervention group. In contrast, the effect of time was not significant in the control group ($F(1,21) = 2.68$, $p = .117$, $\eta^2 = .113$) (pre-test: M = 8.22, SD = 7.08, post-test: M = 7.09, SD = 7.54). There was no main effect of gender ($F(1,21) = 0.37$, $p = .550$, $\eta^2 = .017$), but there was a marginally significant time x gender interaction in the control group ($F(1,21) = 3.38$, $p = .080$, $\eta^2 = .138$). More specifically, the errors boys in the control condition made significantly decreased from pre-test to post-test (F(1,13) = 7.28, $p = .018$, $\eta^2 = .359$), while no change was detected for girls (F(1,8) = 0.18, $p = .896$, $\eta^2 = .002$) (for descriptive statistic see Table 17).

Reaction times on correct trials were also analysed. As shown in Table 18, there were no significant effects on the pre-test (for descriptive statistic see Table 17).

When testing the effects of the intervention, as shown in Table 16, there was a marginally significant effect of time: the mean reaction time somewhat decreased from pre-test (M = 1.19, SD = 0.36) to post-test (M = 1.09, SD = 0.30). No other main effects (condition, gender) or interaction effects (condition x gender, time x condition, time x gender, time x condition x gender) were observed (for descriptive statistic see Table 17).

5.4.4 Morning cortisol levels.

Post-test cortisol levels. Two children were missing from school during the post-test cortisol sampling thus they were excluded. Further two outliers were excluded on the pre-test results. As shown in Table 18, no effects were significant on the pre-test scores (for descriptive statistic see Table 17).

When testing the effects of the intervention on children’s cortisol levels, as shown in Table 19, there were no main effects of condition or gender and no significant condition x gender, time x condition or time x condition x gender interactions. However, a significant effect of time was found. Cortisol levels in participants’ saliva increased from pre-test (second week of September) (M =0.158, SD = 0.115) to post-test (third week of October) (M = 0.198, SD = 0.129). There was also a significant time x gender interaction. This interaction was further analysed in repeated measures ANOVAs separately for boys and girls. Time was used as a within-subjects factor and condition as a between-subjects factor for both genders. For boys there was no significant effect of time ($F(1,36) = 2.63$, $p = .114$, $\eta^2 = .068$), or condition ($F(1,36) = 0.13$, $p = .910$, $\eta^2 = <.001$) and no time x condition interaction was found ($F(1,36) = 0.000$, $p = .992$, $\eta^2 = <.001$) (for descriptive statistic see Table 17). For girls, however, time had a significant effect ($F(1,20) = 12.98$, $p = .002$, $\eta^2 = .394$): cortisol levels raised from pre-test ($M = 0.145$, $SD = 0.100$) to post-test ($M = 0.216$, $SD = 0.122$). No effects of condition ($F(1,20) = 0.16$, $p = .900$, $\eta^2 = .001$) or the interaction between time x condition were detected ($F(1,20) = 0.09$, $p = .773$, $\eta^2 = .004$).

Follow-up cortisol levels. Seven children were missing from school during follow-up cortisol sampling, and four children had outlying scores on the change from pre-test to follow-up thus they were excluded from the following cortisol analyses. Pre-test differences were also tested in this subgroup of participants and, as shown in Table 18, there were no effects of condition or gender and no significant interaction between the (for descriptive statistic see Table 17). When testing the effects of intervention, as shown in Table 19, there were no significant results: no main effect of time, condition or gender, and no interaction between condition x gender, time x condition, time x gender, or time x condition x gender were detected (for descriptive statistic see Table 17).

Table 19.

Effects of the intervention on cortisol levels

Measu-rement	Repeated-measures ANOVA																											
	time				condition				gender				condition x gender				time x condition				time x gender				time x condition x gender			
	F	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2
Pre-test-post-test	14.06	1,55	<.001	.204	0.06	1,55	.811	.001	0.02	1,55	.903	<.001	0.003	1,55	.954	<.001	0.13	1,55	.717	.002	4.18	1,55	.046	.071	0.01	1,55	.915	<.001
Pre-test-Follow-up	0.001	1,46	.971	<.001	0.10	1,46	.753	.002	0.01	1,46	.931	<.001	0.04	1,46	.853	.001	0.54	1,46	.466	.012	0.61	1,46	.441	.013	0.57	1,46	.455	.012

5.4.5 Strengths and Difficulties Questionnaire.

The Strengths and Difficulties Questionnaire was filled in by 54 parents on the pre-test, only 48 of whom filled in the questionnaire on the second occasion (at follow-up) thus only they were included in the following analyses.

Emotional problems. There were five outlying scores on the change from pre-test to follow-up so they were excluded. As the assumptions of univariate ANOVA could not be met, nonparametric tests were run on the pre-test scores. There were no significant differences between the intervention and the control group, or between boys and girls. Neither in the intervention group, nor in the control group were there significant differences between boys and girls. (For statistics see Table 15.)

When testing the effect of intervention, we found no effects of time, condition or gender, and no condition x gender, time x gender and time x condition x gender interactions, as shown in Table 20. A marginally significant time x condition interaction was found (for descriptive statistic see Table 21). In order to unveil this, we used repeated measures ANOVAs separately for the two conditions, with time as a within-subjects factor and gender as a between-subjects factor. In the intervention group no effects of time ($F(1,22) = 0.17$, $p = .681$, $\eta^2 = .008$) or gender ($F(1,22) = 0.50$, $p = .487$, $\eta^2 = .022$) and no significant time x gender interaction ($F(1,22) = 0.001$, $p = .970$, $\eta^2 < .001$) were found. In the control group, there was no significant effect of gender ($F(1,17) = 0.17$, $p = .689$, $\eta^2 = .010$) or a time x gender interaction ($F(1,17) = 0.64$, $p = .435$, $\eta^2 = =.036$). There was a significant effect of time in the control group, however ($F(1,17) = 6.22$, $p = .023$, $\eta^2 = .268$): emotional problems scores increased from pre-test ($M = 1.32$, $SD = 1.11$) to follow-up ($M = 1.89$, $SD = 1.41$) in the control group.

Conduct problems. There was one outlier on the change from pre-test to follow-up and thus had to be excluded. For testing baseline differences an additional two outliers were excluded from the dataset. As shown in Table 18, there was a significant effect of gender on pre-test: boys had significantly higher scores ($M = 2.33$, $SD = 1.88$) on this scale than girls ($M = 1.00$, $SD = 1.12$). There was no significant main effect of condition and no interaction between condition and gender (for descriptive statistic see Table 21).

When testing the effect of the intervention, as shown in Table 20, there were no significant effects of time or condition, and no condition x gender, time x condition, time x gender or time x condition x gender interactions (for descriptive statistics see Table 21). A significant main effect of gender was observed: boys had higher scores on this scale both at pre-test (*M* = 2.33, *SD* = 1.88) and post-test (*M* = 1.93, *SD* = 1.59) than girls had on pre- (*M* = 1.00, *SD* = 1.12) and post-test (*M* = 0.90, *SD* = 0.91).

Hyperactivity. We excluded two participants with outlying scores on the change from pre-test to follow-up. Again, as shown in Table 18, a gender difference was detected on pre-test: boys have significantly higher hyperactivity scores (*M* = 4.46, *SD* = 2.46) than girls (*M* = 2.89, *SD* = 2.27). No significant difference between the two conditions, and no condition x gender interaction were detected (for descriptive statistic see Table 21).

When testing the effect of the intervention, there were no effects of time or condition or any of the interactions (condition x gender, time x condition, time x gender, time x condition x gender), as shown in Table 20. The main effect of gender was significant: boys were reported to be more hyperactive on both pre-test (*M* = 4.46, *SD* = 2.46) and post-test (*M* = 4.25, *SD* = 2.52) than girls on pre-test (*M* =2.89, *SD* = 2.27) and post-test (*M* =3.06, *SD* = 1.95) (for further descriptive statistics see Table 21).

Prosocial behavior. Two outliers in terms of the change from pre-test to follow-up were excluded. Regarding the baseline differences, as shown in Table 18, no significant condition or gender main effects and no significant condition x gender interaction were detected (for descriptive statistic see Table 21). When testing the effect of the intervention, as shown in Table 20, there were no effects of time, condition or gender. We did not find any interaction effects between condition x gender or time x condition x gender either. However, a marginally significant time x condition interaction was detectable. Regarding the time x condition interaction, further analyses showed that in the intervention group there was a marginally significant main effect of time ($F(1,22) = 3.56$, $p = .072$, $\eta^2 = .139$) showing that children's prosocial behavior increased in the intervention group from pre-test (*M* = 7.88, *SD* = 1.70) to post-test (*M* = 8.29, *SD* = 1.70), while no such effect was found in the control group ($F(1,20) = 0.61$ $p =.443$ $\eta^2 = .030$). There was no significant main effect of gender in the intervention group ($F(1,22) = 0.11$, $p = .740$, $\eta^2 = .005$), however, there was a marginally significant time x gender interaction ($F(1,22) = 3.56$, $p = .072$, $\eta^2 = .139$). No significant effect of time was found for the boys in the intervention group ($F(1,14) = 0.000$, $p = 1.000$, $\eta 2 < .001$), but for the girls in the intervention group there was a significant increase in prosocial behavior from pre-test (*M* = 7.67, *SD* = 2.00) to post-test (*M* = 8.78, *SD* = 0.97) ($F(1,8) = 8.16$, $p = .021$, $\eta^2 = .505$). In the control group no significant main effect of time ($F(1,20) = 0.61$, $p = .443$, $\eta 2 = .030$) or gender ($F(1,20) = 0.08$, $p = .782$, $\eta 2 = .004$) and no significant time x gender interaction ($F(1,20) = 0.61$, $p = .443$, $\eta 2 = .030$) were found.

Table 20.

Effects of the intervention on the Strengths and Difficulties Questionnaire scales

Scale	Repeated-measures ANOVA																											
	time				condition				gender				condition x gender				time x condition				time x gender				time x condition x gender			
	F	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2	*F*	*df*	*p*	η^2
Emotional problems	1.44	1,39	.237	.036	0.002	1,39	.967	<.001	0.61	1,39	.439	.015	0.05	1,39	.817	.001	3.35	1,39	.075	.079	0.21	0,39	.650	.005	0.27	1,39	.61	.007
Conduct problems	1.84	1,43	.182	.041	1.57	1,43	.217	.035	7.70	1,43	.008	.152	0.07	1,43	.795	.002	0.19	1,43	.665	.004	.553	1,43	.461	.013	0.41	1,43	.527	.009
Hyper-activity	0.001	1,42	.972	<.001	0.55	1,42	.464	.013	4.16	1,42	.048	.090	0.00	1,42	.988	<.001	2.23	1,42	.143	.050	0.29	1,42	.594	.007	0.02	1,42	.877	.001
Prosocial behavior	0.76	1,42	.388	.018	0.03	1,42	.859	.001	0.001	1,42	.975	<.001	0.19	1,42	.666	.004	3.68	1,42	.062	.081	3.68	1,42	.062	.081	0.76	1,42	.388	.018

Table 21.

Scores on the Strengths and Difficulties Questionnaire on pre-test and follow-up assessment

Scale	Pre-test								Follow-up							
	intervention				control				intervention				control			
	boy		girl		boy		girl		boy		girl		boy		girl	
	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*	mean (*SD*)	*n*
Emotional problems	1.867 (1.506)	15	1.444 (1.509)	9	1.333 (1.323)	9	1.300 (0.949)	10	1.733 (1.335)	15	1.333 (1.936)	9	2.111 (1.961)	9	1.700 (1.160)	10
Conduct problems	2.563 (2.065)	16	1.333 (1.225)	9	2.000 (1.612)	11	0.727 (1.009)	11	2.188 (1.721)	16	1.000 (1.118)	9	1.546 (1.368)	11	0.818 (0.751)	11
Hyperactivity	4.875 (2.473)	16	3.333 (2.646)	9	3.917 (2.429)	12	2.444 (1.878)	9	4.250 (2.265)	16	3.111 (2.261)	9	4.250 (2.927)	12	3.000 (1.732)	9
Prosocial behavior	8.000 (1.558)	15	7.667 (2.000)	9	8.500 (1.446)	12	8.100 (1.524)	10	8.000 (2.000)	15	8.778 (0.972)	9	8.083 (1.929)	12	8.100 (1.912)	10

6. Discussion and limitations

6.1 Discussion and limitations of Study 1:

Meditation interventions efficiently reduce cortisol levels of at-risk samples: A meta-analysis

6.1.2 Discussion of the results of the analyses

These analyses provide a synthesis of all available evidence regarding the efficacy of meditation interventions on the change in participants' cortisol levels in different sampling sources. Effects were tested not only on the short-, but also on the long-term. Additionally, we assessed whether participants at a risk for elevated cortisol levels (e.g., due to mental and somatic illnesses or a stressful life situation) benefit more from these interventions as compared to no-risk samples. We extended previous results by an exhaustive review of the available evidence: we included studies with any sources of cortisol sampling (saliva, blood, urine or hair), any types of meditation interventions, any control conditions (active or passive) and any samples of participants. Still, it should be noted that most of the included studies utilized a meditation program based on mindfulness. Risk of bias was also evaluated.

In 10 randomized controlled trials including data of 395 participants, there was a significant, medium-sized effect of meditation interventions on changes in cortisol levels in blood samples (g = 0.62), however, there were some concerns about the risk of bias in the included studies. The publication bias indicators did not suggest any problems, so the effect seems to be robust. This finding is in line with the result of Pascoe et al. (2017) who found a medium-sized effect of meditation interventions on blood cortisol.

There was a significant, medium-sized benefit of meditation interventions for at-risk samples and a non-significant but large effect for no-risk participants when considering blood samples. More specifically, meditation interventions showed a large, significant effect on cortisol for samples with a somatic illness and no effect for samples with mental problems. Thus, partially in line with our expectations and the mindfulness stress buffering account of Creswell and Lindsay (2014) who predicted more benefits of mindfulness interventions for at-risk samples (people experiencing a large amount of stress or having an illness that is susceptible to stress), upon closer inspection we only found a significant effect for samples with a somatic illness. It should be noted that there were only two no-risk samples in the studies focusing on blood cortisol and we did not have enough statistical power to statistically contrast effects for the different samples. Thus, these results should be considered preliminary.

When assessing results on salivary cortisol, there was no main effect of meditation interventions or any effects for at-risk or no-risk samples either. However, there was a moderate-sized benefit of these programs for samples living in stressful life situations such as low-income family members, dementia caregivers, cancer survivors or cancer patients. Additionally, when we focused on adult participants only, there was a marginally significant, small effect for no-risk samples. It should be noted that we found signs of a possible publication bias and the average effect size was not robust. Moreover, the risk of bias in the primary studies was categorized as 'some concerns' with one exception, thus the results should be regarded cautiously. The reason for this categorization in most cases was a lack of a statistical analysis plan reported.

In sum, we found differential main effects of meditation interventions on blood and saliva samples, however, we suspect that it is due to the larger ratio of studies with at-risk samples and, more specifically, patients with a somatic illness in the studies focusing on blood samples. This is also conceivable as access to blood samples is more likely in studies including hospitalized samples as compared to studies utilizing saliva samples. Upon closer inspection, both sets of studies seem to show, in line with our hypothesis, that meditation interventions are especially beneficial for samples at a risk for elevated cortisol levels.

A puzzling finding is that meditation interventions showed no effects, based on the available three studies on blood cortisol and three studies on salivary cortisol for participants with a diagnosis or symptoms of a mental disorder. This contrasts previous results showing the benefits of meditation for symptoms of depression and anxiety (Goyal et al., 2014). Further research is warranted.

In contrast to previous reviews, we intended to conduct meta-regression analyses to test the sustained effect of meditation interventions on follow-up assessments. We could only test this variable on saliva samples. Surprisingly, when focusing on the results of the cortisol sampling furthest in time from the end of the intervention, we did not find any significant effect of the time between the end of the intervention and the sampling on the effect size on salivary cortisol. This is a very preliminary result, but it seems to suggest that effects do not disappear with time. We have no information regarding whether participants sustained a meditation practice after the intervention, but it is also plausible that a few weeks long meditation program could provide participants with strategies of stress management that are used on the long-run, even without a lasting meditation practice. At the same time, we would like to emphasize that only a very limited number of studies provided information on more than three-month follow-up assessment. Further studies including repeated assessments over longer periods of time are needed.

An interesting finding of the present study was the significant effect of the length of the interventions on the effect size in case of blood samples suggesting that longer meditation programs were more effective in stress reduction. This result has important practical implications. Interventions longer than 20 hours seem to be most effective as shown in Figure 6.

Finally, in contrast with Sanada et al. (2016) results regarding salivary cortisol, a puzzling finding of the present study is a marginally significant effect of gender ratio in the studies assessing blood cortisol. We found that meditation interventions might be more effective for men.

6.1.2 Recommendations for future research

Based on our results and the state of the available scientific evidence, further research is clearly needed. As our results show, the available information regarding the effect of meditation programs on cortisol levels of people with mental problems is very limited. Further RCTs should focus on homogeneous samples with diagnosed mental disorders in order to get a clear picture on the effectiveness of these techniques for such populations. Although Goyal et al. (2014) found that mindfulness has beneficial effects on symptoms of anxiety and depression, it is not clear yet whether this effect can also be confirmed by cortisol results. Furthermore, with substantially more studies focusing on homogeneous samples with mental disorders future meta-analyses will be able to investigate for which disorders meditation interventions might be beneficial. In contrast, it seems that meditation can be beneficial in case of somatic problems (based on blood cortisol results) and for people in stressful life situations (based on salivary cortisol results). However, these categories were still very heterogeneous. Further RCTs with a variety of somatic disorders and stressful life situations will enable more specific suggestions. Another gap in the literature is that most of the evidence come from adult samples. In fact, we only found two studies assessing the effects of a meditation intervention on children’s cortisol levels (Schonert-Reichl et al., 2015; Sibinga et al., 2013). It is not clear yet if these techniques could be effective in reducing children’s cortisol levels because the available results are contradictory. Further RCTs should be conducted with children. Measurement of cortisol levels from saliva, hair and urine are non-invasive procedures that can be easily implemented with children. An interesting result of the present study is that meditation interventions might be more effective for males than for females. Further studies should directly contrast the efficacy of programs for the two genders and investigate the possible reasons for this difference. Finally, the field should be more rigorous regarding the design of RCTs and limit the moderate level risk of bias found in the present meta-analysis. While most of the included studies performed well on the first four domains of the Cochrane Collaboration's risk of bias tool 2.0 (Sterne et al., 2019), almost none of them mentioned that there was a pre-specified analysis plan. Further researches should pre-specify and report a detailed statistical analysis plan.

6.1.3 Recommendations for clinical practice

In contrast to Goyal et al. (2014) findings that symptoms of anxiety and depression can be effectively decreased with mindfulness, we could not confirm this with results on cortisol in the present meta-analysis. However, we found that meditative programs can be used for people in life situations where with a risk for elevated cortisol levels such as caregivers of dementia patients, or in case of people with somatic illnesses (e.g., colitis ulcerosa or Cohn's disease). Additionally, longer programs were found more effective and it is recommended that meditative interventions should last at least hours in order to reach the desired effect (e.g., Jung et al., 2015 or Frisvold, 2009) (see Figure 4).

6.1.4 Recommendations for future meta-analyses

In our meta-analysis we extended previous review results by investigating whether meditation-based programs are equally effective for different populations. With substantially more available primary studies, future meta-analyses will be able to further specify the efficacy of such interventions for different at-risk groups such as people diagnosed with an anxiety disorder.

6.1.5 Limitations

There was a small number of randomized controlled trials of meditation interventions that provided information on changes in cortisol levels that we could include and they used different sample sources (e.g., blood, saliva, urine and hair samples) or sampling schedules (one or more sampling occasion per day, sampling on one or more consecutive days). Unfortunately, only two studies reported on hair and one reported on urine cortisol results, thus this part of the present meta-analysis remains descriptive and preliminary. Accordingly, statistical power in the present meta-analysis was low for all subgroup analyses, however, we had sufficient power to conduct the meta-regression analyses. Furthermore, most studies used a meditation intervention based on mindfulness and thus other schools of meditation are highly underrepresented. Additionally, interventions in the primary studies were complex and not described in details making it difficult to determine what exactly happened during the sessions. We assessed whether effects were larger for samples at a risk for elevated cortisol levels. We reported results for samples with a somatic illness, participants with a diagnosis or symptoms of a mental disorder and subjects living in stressful life situations – conditions that have been shown to be associated with higher cortisol levels. Still, these are highly heterogeneous groups. Without more studies to be included in a meta-analysis like the present one, however, we cannot make more fine-grained analyses. It is important to point out that although we only included randomized controlled trials, the risk of bias in these studies was mostly categorized as 'some concerns'.

Finally, the measurement of cortisol also varied substantially in the primary studies. In case of saliva samples, studies tended to report on less reliable cortisol estimates such as a single sample or a daily average as opposed to indicators such as the AUCg. Furthermore, the risk status of the sample and the source of cortisol sampling seem to be confounded thus it is difficult to make definite conclusions

6.2 Discussion and limitations of Study 2

Short mindfulness-based intervention has no effects on executive functions but may reduce baseline cortisol levels of boys in first-grade.

6.2.1 Discussion of the results of the analyses

In the present study the effects of a short mindfulness-based intervention were tested on pre-schoolers' short-term memory and executive function skills, morning cortisol levels and cortisol reactivity. We assessed the effects of this intervention in the summer of 2017 and 2018 compared to a passive control group in a randomized controlled design. Effects of the intervention on short-term memory, executive functioning and cortisol reactivity were tested before and after the intervention in the kindergarten while, morning cortisol levels were also assessed on follow-up: one week and one month after school entry. This study aimed to confirm the positive effects of mindfulness-based intervention on children's executive function skills (Takacs & Kassai, 2019) and test whether this effect is due to reduction in children's stress levels. We chose a stressful life event, school entry (Groeneveld et al., 2013) to investigate these questions as it seems that mindfulness-based interventions are effective in stressful life situations as it has been shown in the meta-analysis (Study 1).

In contrast to the results of previous systematic reviews (Diamond & Lee, 2011; Takacs & Kassai, 2019), our results showed no effects of the mindfulness program on children's working memory or cognitive flexibility. Unfortunately, due to a floor effect, we could not test the effects on inhibitory control skills. The discrepancy in the findings in the present study and the previous literature might be due to relatively short intervention that we applied (only 5 sessions long, while mindfulness-based interventions are usually conducted over 8 sessions) and the pacing of the program as the 5 sessions were conducted over only a week. Thus, a short and intense mindfulness program might not be as effective in fostering children's executive functioning as the interventions that were found effective in previous studies. For instance, the length of mindfulness interventions in a meta-analysis focusing on fostering children's executive functioning ranged from eight to 25 sessions (Takacs & Kassai, 2019). More specifically, the study that showed improved working memory capacities used an eight-session long (one hour per session) program (Abd et al., 2016). Another study that found better inhibitory control skills applied an 18-session long program with 20-minute long sessions (Viglas, 2015). Finally, a third study showed improved cognitive flexibility (Parker et al., 2014) in which the Master Mind curriculum was used, which is a four-week long program with 20 lessons. Additionally, the majority of the previous experiments that found positive effects in the aforementioned meta-analysis applied tests of inhibitory control (Takacs & Kassai, 2019), the results on which we could not analyse. Future studies should assess the specific effects of mindfulness program on the different components of children's executive function skills. Also, the possibility of insufficient statistical power due to the small sample size should not be excluded.

Similarly, there was no effect of the intervention on children's short-term memory. Surprisingly, children's performance was found to decrease from pre- to post-test, regardless of the condition. This finding is puzzling and might be due to children's fatigue and decrease in interest, as there was only one week between the pre- and the post-test.

In order to assess children's baseline stress levels and cortisol reactivity, we applied an objective biomarker, salivary cortisol levels. In contrast to what we expected, the intervention had no effects on children's baseline cortisol levels on post-test, at the end of August. However, we found a significant interaction between condition and gender on the change in cortisol levels from pre-test to the first follow-up taken right after started elementary school in the first week of September. That is, cortisol levels of boys in the mindfulness condition seem to decreased, while that of in the control group did not: in fact, there was a tendency for an increase. This difference was large in magnitude. Finally, this gender x condition effect faded for the second follow-up assessment on the first week of October. Thus, the mindfulness program applied in kindergarten in August had a beneficial effect on boys' stress levels a couple of weeks later right after school entry. The fact that this effect appeared on the assessment in September and not either on post-test or on the second follow-up in October might be explained by the finding that school entry is a stressful life event (Groeneveld et al., 2013) on which a stress reduction program could show a visible effect as shown in Study 1 (Creswell & Lindsay, 2014; Koncz et al., 2021a).

Additionally, the effect appeared only for boys who showed higher levels of cortisol on pre-test. This is in line with the results of Sibinga and colleagues (2013) and with the finding that meditation interventions are most effective in reducing cortisol levels for populations with larger initial cortisol levels (Koncz et al., 2021a). Regarding the effects of gender on the efficacy of mindfulness programs, the results of previous meta-analyses vary. While Sanada and colleagues (2016) did not find a gender effect in studies regarding salivary cortisol levels in adult samples, we (Koncz et al. 2022), who could include only two studies with children samples, showed that the meditation interventions are more effective for reducing males' salivary cortisol.

6.2.2 Recommendations for future research

Future research should take gender into account when assessing stress reduction by mindfulness programs in child samples. It is important to note that we sampled children from eight state preschools in average-SES neighbourhoods thus we suspect that the results can be generalized to the middle-SES population. Further studies need to be conducted with disadvantaged samples.

6.2.3 Limitations

First of all, it should be noted that the number of the participants was low in the present experiment, particularly regarding the post-test data so it may be worthwhile to repeat the experiment with a larger sample. Secondly, data collection was implemented during two summers and most likely due to measurement error, there was a significant difference between the cortisol values in the two cohorts, however, this difference was eliminated by standardizing the scores. Additionally, cortisol sampling could not be synchronized to waking time, and there was a significant difference between the school and preschool sampling times thus we could not test whether school entry elevated children's cortisol levels. Thirdly, the intervention used in the current study was a short, 5-session program that included yoga exercises in addition to mindfulness practices presented in the context of a narrative story, while mindfulness programs are often longer, consisting of about 8 sessions. In fact, Koncz et al. (2021a) found that longer meditation interventions are more effective in reducing cortisol levels. We have to emphasize however, that such interventions must be adjusted to the needs and attention span of the target population and the possible circumstances, and this consideration confirms our decision toward a brief intervention.

6.3 Discussion and limitations of Study 3

Benefits of a mindfulness-based intervention upon school entry on executive functions and behavioral problems

6.3.1 Discussion of the results of the analyses

In this study the effects of a six-session long mindfulness-based intervention was observed, compared to a passive control group, on first-graders' executive function skills, short-term memory and sustained attention by computerised tasks. This is a slightly modified version of a previous study (see Study 2) (Koncz et al., 2022) The impact of the program on children's cortisol level, a biomarker of stress, on short-term (one week after finishing the program) and on the long run (one month after the program) was also tested in order to assess whether the positive effects of mindfulness interventions on children's executive functioning can be, at least partially, explained by reduction in stress levels. Additionally, children's behavior problems were also assessed at pre-test and follow-up to test the effects of the intervention. We aimed to reveal whether a six-session-long mindfulness-based program applied in school could be effective in improving executive function skills as previous literature found evidence for somewhat longer programs (Takacs & Kassai, 2019). Moreover, we also examined whether the program decreases children's stress levels because there is evidence from Study 1 for such an effect for adults but results regarding children are still very limited. In our meta-analysis (see Study 1) (Koncz et al., 2021a) we found only two studies with participants under 18 years. There are two additional studies (Study 2, Koncz et al., 2022; Study 3, Koncz et al., 2021b) that provide evidence of the effectiveness of mindfulness interventions on cortisol levels. It has also been proposed that such bottom-up mechanisms are at work behind the benefits of mindfulness practices for children's executive functioning (Zelazo & Lyons, 2012). Finally, the effects on participants' behavior problems and prosocial behavior were also tested to confirm previous results of Cheang and colleagues (2019) who found that mindfulness programs nurture children's empathy and compassion. This effect could not be tested in Study 2 due to the lack of questionnaires filled out by the parents. It should be noted that, unlike other mindfulness programs, prosocial behavior was not directly addressed in the intervention of the present study so we tested whether mindfulness practices have an indirect effect on those skills.

Regarding children's executive function skills, we found some evidence for the benefits of mindfulness practices. Partly in line with previous meta-analytical results of Takacs and Kassai (2019), we found positive effects on working memory and also on children's cognitive flexibility for which the meta-analysis did not find evidence. First, working memory capacity significantly improved in the mindfulness but not in the control condition when inspecting data of the girls in the sample. The same was not found for boys. Second, a puzzling finding is children made more errors of inhibitory control after the intervention compared to controls. When inspected separately for the two genders, girls were found to improve in the control, but not in the intervention condition. Third, the mindfulness group improved on cognitive flexibility. Surprisingly, boys in the control condition also did, while the girls did not. It should also be noted that although we matched participants on the pre-test results of the executive function tests before random assignment to either the intervention or the control group, due to the cases we had to exclude from the analyses there were significant baseline differences on inhibitory control and cognitive flexibility in the subsamples whose data could be used in those analyses. These pre-existing differences might have affected the results.

In sum, while we found some evidence for the efficacy of mindfulness training, results on executive function skills depict somewhat more nuanced effects: it seems that the mindfulness program made somewhat different gains for the executive function skills of boys and girls in the sample. The present results are the first, to our knowledge, to highlight the possible moderating role of gender in this line of research. Further research is warranted.

We used an adapted version of the intervention we had applied in Study 2. We extended the original program by adding an extra session at the beginning of the program about stress in order to put the intervention in context and a discussion at the end of each session summarizing the conclusions. While in that experiment we found that the mindfulness intervention prevented a rise in boys' cortisol levels upon school entry, we found no effects on children's executive function skills. Since the modifications we made to the program was not the only difference between the two experiments because also the timing of the intervention was different (before school entry versus right after school entry) and also, we chose somewhat different measurement instruments, we cannot conclude that it was the extension to the program we made that resulted in positive effects on executive functioning.

We found no evidence in the present study that the mindfulness intervention reduced children's stress levels. This finding is in contrast to the results of the previous experiment (Study 2) showing that a mindfulness program applied before school entry prevented a rise in boys' stress levels when starting school (Koncz et al., 2022). Similarly, Sibinga and colleagues (2013) found a protective effect of a mindfulness-based stress reduction program among boys from low-income families from seventh and eighth grade against an increase in cortisol levels. These findings are instead in line with Schonert-Reichl and colleagues (2015), who did not find any positive effect among fifth-graders. Further research is still needed to clarify these differential findings.

We aimed to measure the effects on cortisol levels in order to test the hypothesis that the positive effects of mindfulness practices on children's executive function skills are, at least partially, due to bottom-up processes such as reduction in stress (Zelazo & Lyons, 2012). As we found no effects of the intervention on cortisol levels, the present study does not confirm such bottom-up processes. Instead, this finding implies that it is top-down processes such as practicing conscious control over one's attention that is the mechanism for the benefits of mindfulness practices on children's executive functioning. Future research should investigate the role of these mechanisms.

In fact, the only finding regarding cortisol levels was that girls experienced an increase from September to October. This result might provide a more fine-tuned account of a previous finding showing that school entry is a stressful life event (Groeneveld et al., 2013): it seems from our results that school entry might be especially stressful for girls. This might be because girls could be under more pressure for good academic achievement and easy social adaptation due to gender stereotyping (Eagly, 2009; Hartley & Sutton, 2013; Heyder & Kessels, 2013). However, this issue should be further investigated.

Finally, we found positive effects of the intervention on children's emotional problems and prosocial skills. The mindfulness program seems to have had a protective effect because emotional problems increased over time only in the control and not in the intervention group in line with previous meta-analytical results of Maynard and colleagues' (2017). Additionally, somewhat in line with Cheang and colleagues' (2019) findings, the intervention improved prosocial behavior, but only for girls and not for boys. Again, we found evidence for the moderating role of gender for the benefits of mindfulness practices for children. It should be noted that unlike other mindfulness-based programs for children, the intervention in the present study did not directly target prosocial skills. Thus, this result might suggest that mindfulness practices have an indirect effect on girls' prosocial behavior.

The intervention did not have a beneficial effect on other behavior problems reported by the parents such as hyperactivity and conduct problems. This is in line with Maynard and colleagues' (2017) results who did not find any significant effect of mindfulness-based programs on behavioral outcomes, but the result is in contrast to the results of previous meta-analyses showing positive effects of mindfulness-based programs on inattention and hyperactivity in children (Vekety et al., 2020) or negative behavior (Dunning et al., 2018).

6.3.2 Limitations

This study could be methodologically improved by synchronising the timing of all the cortisol sampling to waking, although these samplings were taken in a narrow time frame: between 7:30 to 8:00 a.m. On the other hand, the intervention was somewhat shorter (6 sessions) than the most commonly used mindfulness programs (about 8 sessions). Additionally, this program included not just mindfulness but psychoeducational content and yoga embedded in a narrative story. These characteristics of the intervention might make it difficult to compare the results to the findings of previous studies.

6.4 Discussion of the doctoral work

6.4.1 Main results

The aim of this doctoral work is based on the findings that self-regulatory skills could be improved by practicing meditation (Takacs & Kassai, 2019). The main goal was to test whether this effect could be explained by stress reduction which can be seen as a bottom-up process (Zelazo & Lyons, 2012). First of all, we reviewed the results of randomised controlled trials available in the literature that examined the stress-reducing effect of any type of meditation that had been measured by the level of the stress hormone, cortisol. In addition, we tried to reveal what background variables can influence the stress-relieving effect of meditation. The vast majority of studies, with a few exceptions, examined mindfulness meditation. Results have shown that meditation is effective in reducing stress levels, especially in at-risk groups. This result seems to support Creswell and Lindsay's stress buffering hypothesis that mindfulness may have the most stress-relieving effect on those who are somehow at a risk of elevated cortisol levels.

An important literature gap is that in this meta-analysis study, we found only two studies with participants under the age of 18 that examined the cortisol lowering effect of meditation and their results are contradictory. Furthermore, Takacs & Kassai (2019) found only 6 studies in their meta-analysis examining the effect of meditation on executive functions, however based on their results, this is a promising technique. From what was written above it can be seen that no randomized controlled trial was available that would simultaneously examine the effect of meditation on cortisol levels while also measuring executive functions. Due to the lack of such trials, it was not possible to test the hypothesis of Zelazo and Lyons (2012) about the mechanism of mindfulness affecting children through top-down and bottom-up processes.

As a next step, in light of the above-mentioned literature gap, we designed a trial in which we examined the effect of a short story-based mindfulness program on executive functions and cortisol levels in the pre-school period, and also measured cortisol levels after school entry. As this is a stressful life event (Groeneveld et al 2013), we expected a decrease in cortisol levels in the intervention group which may confirm the above-mentioned stress buffering hypothesis. The results showed that although there is no effect on executive functions (in contrast with Takacs & Kassai 2019), there is a gender difference in the effect of mindfulness on cortisol levels after school entry. The intervention may have a protective effect against a rise in cortisol levels after school entry. This supports the theory of Creswell and Lindsay and in line with Sibinga and colleagues' (2013) results who found a stress-relieving effect among boys who were in a stressful life situation that was being a member of a low-income family. These results are also in line with the results obtained in the meta-analysis (Study 1) (Koncz et al., 2021a), where based on the results, in the case of blood samples, meditation seems to have a stronger effect on lowering cortisol levels in men.

In the third study, the intervention used in the second study was further developed and applied among first graders after starting school. Before the story-based mindfulness intervention, participants could learn about stress and ways to reduce it, and after each story-based session, participants discussed what happened on that day and they repeated what they had learnt with helping questions. Although, similarly to the previous study (Study 2) we expected an improvement in executive functions and decrease in stress, in fact we were unable to repeat our previous result, meaning, we did not find any stress-reducing effect. Considering the executive functions, working memory improved in girls while cognitive flexibility improved in the whole intervention group, these results are partly in line with the previous meta-analysis of Takacs and Kassai (2019).

Interestingly, while the results of the first study, the meta-analysis, and the subsequent trial (Study 2) both seem to confirm the stress buffering hypothesis, the third study failed to confirm this result. It is possible that if children participate in the intervention before the stressful event (e.g., school entry), it may be more likely to have an effect on their cortisol levels, but after starting school it is less effective in this regard. In future studies, it would be worthwhile to examine the effects of mindfulness in the case of high school students who are about to graduate. Importantly, in the third study we confirmed that mindfulness contributes to reducing children's emotional problems, as it was found by Maynard and colleagues (2017), and that girls 'prosocial abilities have also developed, which is consistent with Cehang and colleagues' (2019) findings.

Gender differences were found in all three studies. For males, meditation seems to be more effective in reducing cortisol levels. This is what we found in the meta-analysis (Koncz et al., 2021a) and cold be supported by the results of the first field experiment (Koncz et al., 2022), and it is also consistent with Sibinga and colleagues' (2013) results. On the other hand, we found positive effects for girls in working memory and prosocial skills in the second field experiment (Koncz et al., 2021b). These results are odd if we assume that stress has a mediating effect and that stress reduction is a possible mechanism of mindfulness that contributes to the development of executive functions. In order to decide the role of stress it would be beneficial to show these effects in the same study. What can be assumed, however, is that mindfulness may affect boys and girls differently.

Placing the results of field experiments in the literature, we can see that the stress reducing effect found in Study 2 (Koncz et al., 2022) is consistent with the meta-analytical results that found that mindfulness-based interventions can reduce stress and anxiety (Chiesa et al., 2009; Dunning et al., 2018; Kallapiran et al., 2015; Koncz et al., 2021a; Pascoe et al., 2017; Sanada et al., 2016), but the results of the second field experiment (Study 3) (Koncz et al., 2021) do not support this. As far as executive functions are concerned, the results of the second field experiment (Study 3) (Koncz et al., 2021b) agree with the results of the meta-analyses that mindfulness can have a positive effect on executive functions (Dunning et al., 2018; Takacs & Kassai, 2019). And finally, although unfortunately only the second field experiment (Study 3) (Koncz et al., 2021b) was able to examine the impact of mindfulness on behavioral problems, the result obtained in case of prosocial behavior is the same as found in previous meta-analyses: mindfulness can improve prosocial behavior (Donald et al., 2018; Dunning et al., 2018). Some meta-analytic findings suggest that mindfulness reduces hyperactivity, inattention (Vekety et al., 2020) and aggression (Dunning et al., 2018), but we found no such effect. It is important to note that our study was conducted with typically developing and not problematic children.

Although Creswell and Lindsay’s (2014) stress buffering hypothesis appears to be supported by the results of this doctoral work, the two studies conducted with children and the results in the literature so far are, however, contradictory in this regard. As it has been pointed out before, we did not receive an answer as to whether stress really mediates the development of executive functions. Related to the contradictory results and the failure to prove a mediating effect of stress, it is important to note that statistical power in the two field experiments was limited, thus non-significant results should be regarded cautiously.

6.4.2 Future research

It can be seen that the effects of mindfulness on stress-reduction and the improvement of executive functions regarding children still create confusion, so there is still a need for randomized controlled trials with children concerning this topic. Although there are already curricula that teach mindfulness techniques to children, such as the Kindness Curriculum (Flook et al., 2015), MindUP (Maloney et al., 2016) or Learning to BREATHE (Broderick & Frank, 2014) these are not yet widespread enough. In the long run, it could be beneficial to train teachers to incorporate these techniques into their daily teaching routine. As the results show, it can be especially useful in stressful life situations not only for adults but perhaps for children as well. Children from low socioeconomic status families who have higher levels of cortisol (Lupien et al., 2001) and have poorer executive functions (Haft & Hoeft, 2017) could probably benefit from practicing mindfulness. It could be particularly beneficial to incorporate the practice of mindfulness techniques into the curriculum used around school entry, even for first-graders in the first weeks because, as it can be seen, in addition to reducing stress it can also reduce emotional problems, and it can also play a role in developing prosocial skills, which could contribute to a better classroom atmosphere.

Based on the results of our meta-analysis (Koncz et al., 2021a), adults with a somatic illness may also benefit from these programs, it can be assumed that this might also be true for children so, for example, children could participate in mindfulness sessions during their hospital stay, thus reducing their stress and consequently, their cortisol levels if they have diseases associated with elevated cortisol levels. However, not only in hospitals, but also in the case of chronic diseases such as diabetes discovered in childhood, it may be worthwhile to incorporate the practice of these techniques into the daily habits of children. These types of techniques could even be learned by the parents, who can later teach it to their children thus contributing to their well-being.

7. Conclusion

In sum, practicing meditation seems to be effective in reducing cortisol levels in cases where there is a risk of having elevated cortisol. These techniques may be also effective for children in case of stressful life circumstances. Hence, this may be a promising intervention in stressful life situations such as school entry, however there may be a gender difference, therefore it could be more effective for boys. In addition to stress reduction, mindfulness also has a role to play in the development of executive functions, but it is conceivable that there may be some gender effects here as well.

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References marked with an asterisk indicate studies included in the meta-analysis. In-text citations to studies selected for meta-analysis are not preceded by asterisks.

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Appendix

Appendix 1

The search string utilized in title and abstract to allocate all relevant publications for the meta-analysis:

(cortisol OR adrenocortic* OR glucocortic* OR hydrocortisone) AND (meditat* OR mindful*) AND (experiment* OR "randomized controlled" OR "randomized control" OR "randomised control" OR RCT)

Appendix 2

Table 1. Results of statistical power analyses of subgroup analyses in the meta-analysis.

Comparison	Statistical power (Blood cortisol)	Statistical power (Salivary cortisol)
Risk status		
No Risk – At risk	-	18%
At risk		
Mental – Somatic	10%	14%
Mental- Stressful life situation	-	12%
Somatic – Stressful life situation	-	16%
Control condition		
Active - Passive	6%	17%
Sampling time		
AM- PM	-	10%
AM- Both	-	20%
PM- Both	-	18%
Sampling procedure		
One sample / day – More samples	-	25%

Table 2. Results of statistical power analyses of meta regression analyses in the meta-analysis.

Regression	Statistical power (Blood cortisol)	Statistical power (Salivary cortisol)
Gender distribution	100%	100%
Mean age	100%	100%
Total intervention time	100%	100%
Elapsed time after intervention	-	100%

Appendix 3

Risk of bias in the included studies in each domain in the meta-analysis.

	Levels of risk of bias					
Study	**Randomization process**	**Deviations from the intended interventions**	**Missing outcome data**	**Measurement of the outcome**	**Selection of the reported result**	**Overall risk**
Bergen-Cico et al., 2014	Low	Low	Low	Low	Some concerns	Some concerns
Bowden et al., 2012	Low	Low	Low	Low	Some concerns	Some concerns
Branström et al., 2013	Low	Low	Low	Low	Some concerns	Some concerns
Carlson et al., 2013	Low	Low	Low	Low	Low	Low
Cash et al., 2014	Low	Low	Low	Low	Some concerns	Some concerns
Chhattre et al., 2013	Low	Low	Low	Low	Some concerns	Some concerns
Fan et al., 2013	Low	Some concerns	Low	Low	Some concerns	Some concerns
Flook et al., 2013	Some concerns	Low	Low	Low	Some concerns	Some concerns
Frisvold 2009	Low	Low	Low	Low	Some concerns	Some concerns
Gagrani et al., 2018	Low	Low	Low	Low	Some concerns	Some concerns
Gainey et al., 2016	Some concerns	Low	Low	Low	Some concerns	Some concerns
Gex-Fabry et al., 2012	Low	Some concerns	Low	Low	Some concerns	Some concerns
Goldberg et al., 2014	Some concerns	Low	Low	Low	Some concerns	Some concerns
Gotink et al., 2017	Low	Low	Low	Low	Some concerns	Some concerns
Hsiao et al., 2016	Low	Low	Low	Low	Some concerns	Some concerns
Jedel et al., 2014	Low	Low	Low	Low	Some concerns	Some concerns
Jensen et al., 2011	Low	Low	Low	Low	Some concerns	Some concerns
Jung et al., 2015	Low	Some concerns	Low	Low	Some concerns	Some concerns
Kim et al., 2013	Low	Low	Low	Low	Some concerns	Some concerns
Lipschitz et al., 2013	No	Low	Low	Low	Some concerns	Some concerns
Marshall et al., 2018	Some concerns	Low	Low	Low	Some concerns	Some concerns
MacLean et al., 1997	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns
Malarkey et al., 2013	Low	Low	Low	Low	Some concerns	Some concerns
Nyklíček et al., 2013	Low	Low	Low	Low	Some concerns	Some concerns
Oken et al., 2010	Low	Some concerns	Low	Low	Some concerns	Some concerns
Prakhinkit et al., 2014	Low	Some concerns	Low	Low	Some concerns	Some concerns
Robert-McComb et al., 2004	High	Low	Low	Low	Some concerns	High
Roeser et al., 2013	Some concerns	Low	Low	Low	Some concerns	Some concerns
Schonert-Reichl et al., 2015	Low	Some concerns	Low	Low	Low	Some concerns
Sibinga et al., 2013	Low	Low	Low	Low	Some concerns	Some concerns
Turan et al., 2015	Some concerns	Low	Low	Low	Some concerns	Some concerns
Van Dam, 2013	Low	Low	Low	Low	Some concerns	Some concerns
Vandana et al., 2011	Low	Low	Low	Low	Low	Low
Zhang and Emory, 2015	Some concerns	Low	Low	Low	Some concerns	Some concerns

Appendix 4

Schedule of the intervention used in study 2

1. day	2. day	3. day	4. day	5. day
1. Breathing meditation Sea cotter cove	**5. Muscle relaxation** Angry octopus	**8. Breathing meditation** Meet again	**11. Relaxation story** Bubble riding	**15. Introductory story**
2. Sensory meditation: Focusing on sounds	**6. Sensory meditation** Touching snail shells	**9. Sensory meditation** Focusing on sounds	**12. Sensory meditation** Mindful eating	**16. Sitting meditation** The pause button
3. Yoga Postures	**7. Sensory meditation** Walking meditation	**10. Sitting meditation** Sitting still like a frog	**13. Short story** Short summary of the bubble riding story	**17. Short storytelling**
4. Breathing meditation Sea cotter cove continued			**14. Sitting meditation** A safe place	**18. Yoga Postures**
				19. Short storytelling
				20. Sitting meditation The conveyor belt of worries
				21. A brief summary of what have been learned during the program

Sensory and breathing meditation tasks and story elements are based on the Hungarian translations of Lori Lite's books like Sea Cotter Cove: A Relaxation Story (Lite, 2014), Angry Octopus: An Anger Management Story introducing active progressive muscular relaxation and deep breathing (Lite, 2008), Bubble Riding: A Relaxation Story designed to teach children visualization techniques to increase creativity while lowering stress and anxiety levels (Lite, 2015) and Sensory meditation tasks are inspired by Susan Kaiser Greenland's Mindful Games: Sharing Mindfulness and Meditation with Children, Teens, and Families (Greenland, 2016)

Sound records of sitting meditations are the modified versions of the Hungarian version of Eline Snel's books sound records: Sitting Still Like a Frog: Mindfulness Exercises for Kids (and Their Parents) (Snel, 2013)

Some of the yoga postures were based on the Hungarian version of Gilles Diederichs' book: Playful relaxation - 35 relaxing games for children (Diederichs, 2014).

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