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ORIGINAL PAPER

Boosting First-Line Mental Health Care for Adolescents Suffering from Chronic Conditions with Mindfulness: Results from a Randomized Staggered Within-Subjects Design

Merle Kock[1,2] · Eline Van Hoecke[4] · Patrick Onghena[5] · Stijn Vandevelde[6] · Mieke Matthyssen[6,7] · Peter Kuppens[2,5] · Filip Raes[1,3] · Katleen Van der Gucht[5,8]

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Abstract

Objectives Adolescents with chronic conditions are at an increased risk for psychopathology, which may impact their quality of life. Reviews suggest that mindfulness-based interventions (MBIs) are promising to support these adolescents. This pilot study investigated the effects of an MBI on emotional distress and quality of life and examined potential mechanisms in adolescents with chronic conditions using a randomized staggered within-subjects design.

Method Twenty-two adolescents (14–18 years) with a chronic condition were randomized to a baseline phase of 14–28 days, followed by an MBI, consisting of four bi-weekly online group sessions. Outcomes were assessed by repeated measurements at the baseline, intervention, and follow-up phases, and by standardized questionnaires and experience sampling measures before randomisation, at post-intervention, and 3-month follow-up. Additionally, interviews were performed.

Results Our main findings showed that stress levels significantly increased ($b = 0.35$, 95% CI [0.12, 0.61]) immediately after the MBI began. However, upon completion of the MBI, participants experienced significant decreases in both depression ($b = -0.44$, 95% CI [−0.72, −0.21]) and stress ($b = -0.36$, 95% CI [−0.63, −0.11]). Quantitative measures revealed no significant effects of the MBI on quality of life. In qualitative interviews, all participants reported that the MBI positively impacted aspects of their quality of life, including a reduction of stress and an improvement in emotional well-being.

Conclusions Based on both quantitative data from repeated measurements and qualitative data from interviews, this pilot study provides preliminary evidence that MBIs are acceptable and safe, and can alleviate emotional distress in adolescents with chronic conditions. Larger, controlled studies are essential to validate and generalize these preliminary findings.

Preregistration This study was preregistered on https://clinicaltrials.gov/ (NCT04359563).

Keywords Mindfulness · Adolescent · Chronic condition · Emotional distress · Quality of life

Chronic illness during adolescence can significantly impact development in physical, emotional, social, and cognitive domains (Yeo & Sawyer, 2005). Managing a chronic condition often entails heightened stress, increasing vulnerability to emotional distress (Brady et al., 2021; Delamater et al., 2017). Furthermore, the chronic condition and its treatment frequently impose functional limitations, diminishing overall quality of life (Santos et al., 2017; Silva et al., 2019). Thus, it is important to identify low-threshold interventions to support adolescents with a chronic condition to cope with their symptoms, improve their functioning, and enhance their quality of life.

Mindfulness-based interventions (MBIs) have shown potential in reducing emotional distress and improving psychological well-being across various populations, including adolescents. MBIs are structured interventions that aim to teach individuals to become aware of thoughts, feelings, and sensations in the present moment, compassionately and without judgment (Kabat-Zinn, 1994). Individuals learn how to break out of habitual and often non-adaptive reactions and instead respond to experiences in a conscious, skilful, and compassionate manner. A review of meta-analyses has suggested that MBIs are more effective than both passive and active controls in reducing psychiatric symptoms, including depression and anxiety, while also improving stress regulation and overall well-being (Goldberg et al., 2021). Additionally, MBIs have been linked to enhanced quality of

Extended author information available on the last page of the article

life in adults with somatic and mental health conditions, as well as in healthy populations (de Vibe et al., 2017). Among children and adolescents, MBIs have demonstrated efficacy in both clinical and healthy populations, with meta-analyses indicating significant reductions in depression, anxiety, and stress, negative behaviours, as well as improvements in mindfulness, attention, and executive functioning (Dunning et al., 2019; Zhang et al., 2022). Given the promising evidence supporting MBIs, further exploration of their effects in adolescents with chronic conditions is warranted.

A recent scoping review has supported the feasibility and acceptability of MBIs for adolescents with chronic conditions, with most studies reporting reductions in emotional distress (Hughes et al., 2023). Consistent with these findings, Vo et al. (2024) showed that adolescents with a chronic medical and/or mental health diagnosis experienced improvements in depressive symptoms, perceived stress, and functional disability after participating in an 8-week in-person MBI. However, findings have been mixed. An uncontrolled feasibility study of an 8-week in-person MBI in adolescents with chronic pain showed improvements in pain acceptance, disability, and pain catastrophizing but no significant changes in quality of life, anxiety, or depression (Suc et al., 2022). Similarly, a pilot randomized controlled trial (RCT) comparing a 6–7-week online MBI to health education in adolescents with type 1 diabetes found no significant between-group differences, though both groups showed reductions in depressive symptoms, anxiety, and diabetes distress, with a trend favouring the MBI for depressive symptoms (Basch et al., 2024). Taken together, previous findings suggest that MBIs show promise for alleviating emotional distress among adolescents with chronic conditions. However, while encouraging overall, findings have been mixed for certain chronic conditions, such as chronic pain and diabetes.

Notably, findings on the effects of MBIs among adolescents with chronic conditions have to be interpreted with caution due to several methodological weaknesses. First, the majority of studies lacked randomisation and control groups, and only included small samples (Basch et al., 2024; Hughes et al., 2023; Suc et al., 2022; Vo et al., 2024). Second, most studies focused on chronic pain patients (Ali et al., 2017; Chadi et al., 2016; Hesse et al., 2015; Jastrowski Mano et al., 2013; Lovas et al., 2017; Ruskin et al., 2014, 2017; Suc et al., 2022), limiting the generalizability of the findings to other chronic physical illnesses. Third, the working mechanisms underlying the effects of MBIs in adolescents are still unclear, while a better understanding of these working mechanisms may help to specifically target mechanisms of action and thereby improve the efficacy of MBIs (Hughes et al., 2023).

Practical barriers also impact the implementation of MBIs for adolescents with chronic illnesses. High time commitment and travel requirements have led to low participation and dropout rates in previous studies (Chadi et al., 2019; Ruskin et al., 2014; Young et al., 2022). One option to address these barriers are digital MBIs. For adults with physical health conditions, a meta-analysis showed that online MBIs reduce depressive symptoms, anxiety, and stress (Liu et al., 2022). Among adolescents with chronic conditions, an RCT found that a 4-week self-guided online self-compassion training improved self-compassion, well-being, and distress compared to a waitlist (Finlay-Jones et al., 2023). However, the completion rate was low (25.00%), mainly due to time constraints. In contrast, an 8-week online program guided by a mindfulness trainer achieved a higher completion rate (77.78%) in adolescents with diverse chronic conditions (Chadi et al., 2019). This suggests that online MBIs guided by trainers may be more successful in keeping adolescents engaged and offer unique benefits, such as peer support (Chadi et al., 2018). Notably, Chadi et al. (2019) found no difference between online and face-to-face MBIs in frequency and duration of homework completion, nor in change of depressive symptoms or anxiety. Only within the online MBI group was there a significant reduction in depressive symptoms and anxiety after the MBI. These results provide preliminary evidence for the feasibility, acceptability, and efficacy of online MBIs in comparison to face-to-face programs, especially when guided by a mindfulness trainer. However, more research is needed to robustly test the effectiveness.

The aim of this pilot study was to investigate the effects of an online MBI on emotional distress and quality of life in adolescents with chronic conditions, utilizing a randomized staggered within-subjects design using multiple baselines (Kock et al., 2021). Advantages of multiple-baseline designs over group-based designs are the smaller sample sizes required to reach the same power (Hawkins et al., 2007) and the possibility to evaluate change processes individually and on a group level. The multiple baselines can be understood as replicated single case studies, which allow us to test to what extent the effects of the MBI can be transferred from one participant to the next (Tanious et al., 2024). In the context of the methodological weaknesses in prior research, this design allowed us to robustly test the efficacy of the MBI across a sample of adolescents with chronic illnesses, including randomization and a control phase, while keeping the sample size and cost relatively low. To address implementation barriers, our MBI consisted of four bi-weekly, instead of eight weekly, group sessions taking place online. A diverse sample of adolescents with any kind of chronic illness was recruited, which allowed us to test whether the effect of our MBI replicates across participants irrespective of their specific chronic condition.

The primary research question was to investigate whether the brief online MBI affects quality of life and emotional

distress (a mean score of depressive feelings, anxious feelings, and stress) and to what extent the effect replicates across a sample of adolescents with chronic illnesses. We hypothesized that the MBI improves quality of life and reduces emotional distress in this sample. The secondary research question was to test whether suppression and acceptance of negative affect, dampening, anhedonia, repetitive negative thinking, or self-compassion mediate the effect of the MBI on quality of life or emotional distress. We expected that the MBI improves quality of life and reduces emotional distress via a decrease in suppression of negative affect, dampening, anhedonia, and repetitive negative thinking, and via an increase in acceptance of negative affect and self-compassion.

Method

Participants

Participants met the following inclusion criteria: (a) being 14–19 years of age, (b) having a chronic condition defined as a condition that lasts at least 1 year and impairs functional ability or requires ongoing medical care, and (c) possessing sufficient proficiency in Dutch. The age range was chosen because heightened brain plasticity around this period presents a window of opportunity for developing new skills (Larsen & Luna, 2018). Adolescents who had a diagnosis of a current or lifetime psychiatric disorder or those receiving treatment for a psychiatric disorder at the time of enrolment were excluded. Participants continued to receive treatment for their chronic condition throughout the study, including psychological support if applicable. Table 1 displays sociodemographic and clinical characteristics of participants at baseline.

Twenty-two adolescents were recruited in two cohorts. Cohort 1 was recruited between May 2020 and July 2020, and Cohort 2 was recruited between August 2020 and June 2021. Staff at the pediatric unit of the University Hospital Ghent, Belgium, identified and handed out study flyers to suitable patients. A researcher contacted interested adolescents and their parents by phone to explain the study procedure and to check for eligibility. After the call, adolescents above the age of 18 years provided written informed consent, while younger adolescents provided written assent, and their parents provided written informed consent to participate. Subsequently, adolescents attended an intake interview with the mindfulness trainer. The Ethics Committee Research UZ/KU Leuven (S63485, leading committee) and the Ethics Committee of Ghent University Hospital and Ghent University gave ethical approval for this pilot study.

Table 1 Sociodemographic and clinical baseline characteristics of each participant

Cohort	ID	Age	Gender	Education level	Diagnosis
1	2	18	Female	Other	Metabolic disorder
1	3	15	Female	General secondary education	Diabetes
1	4	16	Female	Technical secondary education	Diabetes
1	5	14	Male	Vocational secondary education	Diabetes
1	6	16	Female	General secondary education	Chronic fatigue
1	7	17	Female	General secondary education	Chronic pain
1	8	17	Female	Vocational secondary education	Metabolic disorder
1	9	16	Male	Vocational secondary education	Spina bifida
1	10	16	Female	Vocational secondary education	Diabetes
1	11	14	Male	General secondary education	Diabetes
1	12	17	Male	General secondary education	Cancer survivor
1	13	14	Female	General secondary education	Hypotension
1	14	17	Female	General secondary education	Diabetes
1	15	18	Female	General secondary education	Cancer
2	3	17	Female	General secondary education	Traffic accident
2	5	16	Male	Technical secondary education	Cancer
2	6	17	Female	General secondary education	Cancer
2	7	16	Female	Art secondary education	Benign brain tumour
2	8	14	Female	General secondary education	Neurofibromatosis, autism spectrum disorder, kidney failure
2	9	16	Male	General secondary education	Liver transplantation
2	10	16	Female	General secondary education	Chronic pain and nausea

Power calculations detailed in our protocol paper (Kock et al., 2021) yielded a required sample size of $n = 30$ participants (before attrition) to detect an effect on quality of life using self-report questionnaires (SRQs) and $n = 6$ participants to detect an effect on emotional distress using phase measurements (PMs). Due to the high workload in hospitals because of the COVID-19 pandemic, we experienced difficulties with recruitment for Cohort 2. The study design requires all participants of a cohort to start their study participation at a similar time, which led to several participants waiting for months for their cohort to start. To prevent losing participants who had already agreed to take part, we decided to stop recruitment after several weeks of difficulties to recruit additional participants, resulting in a final sample size of $n = 22$.

Procedure

The study was preregistered on clinicaltrials.gov, and the full trial protocol can be found at Kock et al. (2021). A randomized staggered within-subject design was used (Kock et al., 2021). Once recruitment for a cohort was completed (at $n = 15$ and $n = 7$ participants for Cohorts 1 and 2, respectively), participants were randomized to a mindfulness group. For each group, the mindfulness intervention started at different time points. Within each mindfulness group, participants were randomized to different baseline lengths of 2, 2.5, 3, 3.5, or 4 weeks using simple randomization. Due to the smaller sample size in Cohort 2, participants were randomized to baseline lengths of 2, 2.5, 3, or 3.5 weeks. Two participants swapped mindfulness groups because they had recurring evening activities at the same time as the group sessions.

Participants completed daily measurements during the baseline phase. The mindfulness intervention was introduced in a staggered manner, with a half-week time lag across mindfulness groups. To allow for randomized baseline lengths across participants, participants within one intervention group started their baseline phases at varying time points corresponding to their respective baseline lengths. In this way, participants from different intervention groups began their baseline phases at the same time, while starting the intervention at different time points due to their varying baseline lengths, similar to a regular randomized multiple baseline design.

After the baseline phase, participants took part in an MBI. The MBI was delivered according to a standardized protocol (van der Gucht et al., 2017), which is based on Mindfulness-based Cognitive Therapy (Segal et al., 2002) and Mindfulness-based Stress Reduction (Kabat-Zinn, 1990) with adjustments for adolescents. In this pilot study, the protocol was adapted to improve acceptability and practicability of our MBI because prior studies mentioned problems with time commitment in adolescents with chronic conditions (van der Gucht et al., 2017). Specifically, the contents of Sessions 1 and 2, 3 and 4, 5 and 6, and 7 and 8 were combined, while the core elements remained unchanged. The MBI consisted of four bi-weekly 2-hr online sessions and the You-Mind app to assist home practice in-between sessions. The training was delivered in groups of three to five participants, with three groups in Cohort 1 and two groups in Cohort 2. Sessions included guided formal meditations (e.g., body scan, mindful yoga, or sitting meditation), informal mindfulness exercises (e.g., breathing space), reflections, and psychoeducation regarding stress, depression, and self-care. A detailed description of each session can be found at van der Gucht et al. (2017) and the curriculum is available upon request (leuvenmindfulnessconsortium@kuleuven.be). Each MBI group was taught by one of two certified trainers with more than 10 years of experience in mindfulness meditation and extensive experience in working with adolescents. The trainer remained the same for a specific group throughout the MBI. To ensure treatment fidelity, trainers received regular intervision and supervision. Intervision meetings between the two trainers were held 4 and 8 weeks after the start of the MBI for each cohort. Annual supervision meetings were conducted by a mindfulness trainer who was also one of the researchers (KVDG). Both types of meetings focused on ensuring that all components of each session were delivered as intended, discussing the trainers' experiences with the MBI, and addressing any challenges they encountered. Intervision and supervision meetings confirmed that all parts of each session were delivered.

During the intervention phase and the subsequent 3-month follow-up phase, participants completed repeated measurements every 3 days. Additionally, participants of Cohort 1 took part in semi-structured interviews before and after the MBI. Participants received a voucher for a local online store as compensation for their study participation.

Due to the illness of the trainer, the last MBI session for both groups in the second cohort was postponed by a week. Repeated measurements continued during this period. Participants in each of the two cohorts were measured concurrently. They were not blind to the length of the baseline phase because all group members had to be available during the MBI sessions. Mindfulness trainers were blind to the length of participants' baseline phases. This pilot study adhered to the Single-Case Reporting Guideline In Behavioural Interventions (Tate et al., 2016).

Measures

Primary outcomes of this pilot study are emotional distress, conceptualized as the mean score of depressive feelings, anxious feelings, and stress, and quality of life. Secondary outcomes measure potential mechanisms underlying the

effects of the MBI. All outcomes except quality of life are measured in three ways: via repeated PMs, experience sampling measurements (ESM), and SRQs. Additionally, semi-structured interviews were conducted. An overview of all measurements is displayed in Fig. 1.

Phase Measurements (PMs)

Emotional distress was measured using three subscales: depressive feelings, anxious feelings, and stress, each measured with a single-item visual analogue scale (VAS). Eight items captured change in potential mechanisms: suppression/acceptance of negative emotions (two items), anhedonia (three items), dampening (one item), repetitive negative thinking (one item) and self-compassion (one item). Participants indicated how they felt at the present moment (emotional distress, anhedonia) or since the last beep (all other items) on a scale ranging from 0 to 100. Items were taken from Bogaert et al. (2023). The specific items can be found in Online Resource 1. Phase measures were completed daily during the baseline phase and every 3 days during the intervention and follow-up phases on the You-Mind smartphone application (see section Smartphone application). Measures were available from 17.00 on the day of assessment until 16.59 the following day. Before the start of each phase, participants were informed via email about the PM that were about to start the next day (e.g., number of days and time during which phase measures would become available, time window in which measures would need to be completed, advice on how to remember phase measures on a daily basis). Based on prior research (Palmier-Claus et al., 2011), a minimal compliance rate of 30% across all phases was required to be included in analyses. To increase compliance, participants in Cohort 2 were sent an e-mail if they missed more than two measurements in a row. In this email, participants were encouraged to complete a maximal amount of PM and were offered help with technical problems.

Experience Sampling Measurements (ESM)

ESM is a validated structured diary technique that allows for in-the-moment measurements of participants within their daily environment, ensuring high ecological validity. ESM was used to complement PM with more intensive outcome assessments directly before the baseline phase (T1), after the intervention phase (T2), and after the follow-up phase (T3). Participants completed the same VAS scales as described in PM 10 times per day for 4 consecutive days according to a semi-stratified interval scheme (waking hours were divided into 10 equal intervals and one beep was randomly programmed in each interval). ESM could be filled out until 10 min after the beep on the You-Mind app. The day before each ESM assessment started, participants were informed via email about the ESM procedure (e.g., dates during which participants would receive beeps, reminder to turn on notifications on smartphone).

In Cohort 1, overall compliance was low, especially for ESM data, with most participants falling below the minimal compliance rate of 30%. As a result, the minimal required compliance rate for inclusion in data analysis was lowered to 20% for ESM data. To improve compliance for participants in Cohort 2, study compensation was made partially conditional on ESM compliance rates. In Cohort 1, all participants received a €20 voucher as compensation for their study participation. Instead, participants in Cohort 2 received a €10 voucher irrespective of their ESM compliance and could receive an additional €10 voucher if they completed at least 75% of ESM questionnaires at each assessment point. To control for the difference in compensation, cohort was added as a confounding variable in our analyses.

Self-Report Questionnaires (SRQs)

To obtain a fine-grained measurement of all outcomes, SRQs were administered online before the baseline phase (T1), after the intervention phase (T2), and after the follow-up phase (T3) using Qualtrics software (Qualtrics, Provo, UT). The link to SRQs was valid for 1 week to ensure that participants completed SRQs within the same time frame. If participants did not meet this deadline, they were sent a new link and completed the SRQs 1 week ($n = 3$ participants at T2 or T3) or 2 weeks ($n = 3$ participants at T1 or T2) after the deadline. If participants only completed some SRQs, they were sent a new link, which required them to complete

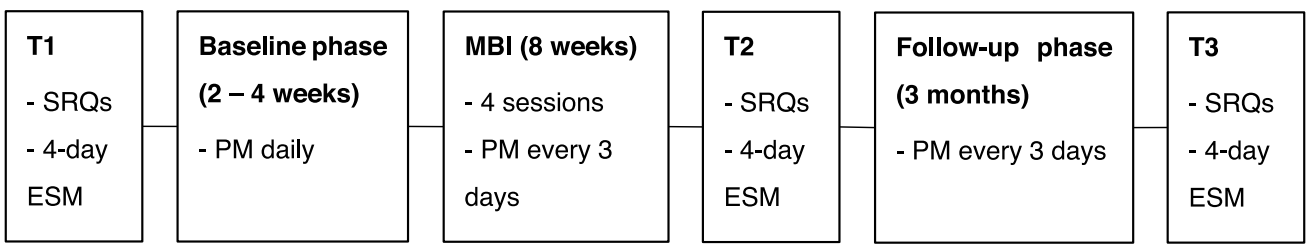


Fig. 1 Overview of measurements across the study phases

all SRQs again. In that case, responses submitted via the first link were retained, and only missing SRQs submitted via the second link were used in analyses to ensure a comparable time frame across participants to the extent possible.

The 23-item adolescent version of the *Pediatric Quality of Life Inventory 4.0* (Peds-QL 4.0; Varni et al., 2001) Generic Core Scales measures quality of life across two subscales: physical functioning and psychosocial functioning, which combine emotional, social, and school aspects. Items are rated on a 5-point Likert scale and rescaled to a 0–100 scale, with higher scores reflecting better quality of life. The Dutch Peds-QL 4.0 evidenced good reliability and construct validity in adolescents with chronic conditions (Engelen et al., 2009). At the three time points, internal consistency for the total score was high ($\alpha = 0.86$ to 0.90; $\omega_t = 0.87$ to 0.92). For the subscales, reliability estimates ranged from 0.73 to 0.88 for Cronbach's α and from 0.81 to 0.91 for McDonald's ω_t. At T3, McDonald's ω_t was computed excluding item 5 of the physical functioning subscale due to a lack of variability, which otherwise produced a computational error.

The *Depression Anxiety Stress Scales* (DASS-21; Lovibond & Lovibond, 1995) were used to measure emotional distress. The DASS-21 comprised three seven-item subscales measuring symptoms of depression, anxiety, and stress over the past week. Items are scored on a 4-point Likert scale, with higher scores reflecting greater symptoms. The DASS-21 has demonstrated good reliability and convergent validity in adolescent populations, with most evidence supporting an overarching emotional distress factor and three specific factors: depression, anxiety, and stress (Dwight et al., 2024). At the three time points, internal consistency for the total score was high ($\alpha = 0.90$ to 0.93; $\omega_t = 0.92$ to 0.93). For the subscales, reliability estimates ranged from 0.81 to 0.90 for Cronbach's α and from 0.78 to 0.90 for McDonald's ω_t, except for the anxiety subscale at T1 ($\alpha = 0.64$) and T2 ($\alpha = 0.40$, $\omega_t = 0.59$).

The *Leuven Anhedonia Self-report Scale* (LASS; Bastin et al., 2018) assesses consummatory, anticipatory, and motivational aspects of anhedonia over the past 2 weeks. Its 21 items are rated on a 4-point Likert scale, with higher scores reflecting greater anhedonia. At the three time points, internal consistency was high ($\alpha = 0.90$ to 0.95; $\omega_t = 0.90$ to 0.96).

The seven-item dampening subscale of the *Responses to Positive Affect Questionnaire* (RPA; Feldman et al., 2008) was used to assess dampening responses to positive affect. Items are rated on a 4-point Likert scale, with higher scores reflecting greater dampening responses. At the three time points, internal consistency was good ($\alpha = 0.81$ to 0.86; $\omega_t = 0.82$ to 0.86).

The 10-item *Non-acceptance and Suppression of Negative Emotions Scale* (NASNES; Bogaert et al., 2023) assesses the extent of suppression compared to acceptance of negative emotions through two subscales. Items are scored on a 7-point Likert scale, with higher scores indicating stronger suppression of negative emotions (suppression subscale) or stronger acceptance (acceptance subscale). At the three time points, internal consistency for the subscales was good ($\alpha = 0.79$ to 0.91; $\omega_t = 0.80$ to 0.92).

The core characteristics subscale of the *Perseverative Thinking Questionnaire* (PTQ; Ehring et al., 2011) measures the main characteristics of repetitive negative thinking: repetitiveness, intrusiveness, and difficulty to disengage. Its nine items are rated on a 5-point Likert scale, with higher scores indicating greater repetitive negative thinking. At the three time points, internal consistency was high ($\alpha = 0.92$ to 0.94; $\omega_t = 0.92$ to 0.95).

The 12-item *Self-Compassion Scale Short Form* (SCS-SF; Raes et al., 2011) measures self-compassion on six subscales: self-kindness, self-judgment, common humanity, isolation, mindfulness, and over-identification. Items are scored on a 6-point Likert scale, with higher scores reflecting greater self-compassion. Following a critical discussion of the factor structure of the SCS in the literature (Muris et al., 2016), both the total score and two subscale scores reflecting self-kindness (mean of three positive subscales) and self-coldness (mean of three negative subscales) were used in this pilot study. At the three time points, internal consistency for the total score was acceptable ($\alpha = 0.68$ to 0.82; $\omega_t = 0.66$ to 0.82). For the subscales, reliability estimates ranged from 0.66 to 0.89 for Cronbach's α and from 0.70 to 0.89 for McDonald's ω_t.

The *Comprehensive Inventory of Mindfulness Experiences—Adolescents* (CHIME-A; Johnson et al., 2017) measures mindfulness skills over the last 2 weeks across eight subscales: awareness of internal experiences, awareness of external experiences, acting with awareness, accepting and non-judgmental attitude, non-reactive decentering, openness to experiences, awareness of thought's relativity, and insightful understanding. Its 24 items are rated on a 6-point Likert scale, with higher scores indicating greater mindfulness skills. At the three time points, internal consistency for the total score was good ($\alpha = 0.77$ to 0.88; $\omega_t = 0.87$ to 0.91). For the subscales awareness of external experiences, openness to experiences, relativity, and insightful understanding, Cronbach's α ranged from 0.72 to 0.90, and McDonald's ω_t ranged from 0.73 to 0.89. For the subscales awareness of internal experiences, acting with awareness, accepting and non-judgmental attitude, and non-reactive decentering, Cronbach's α ranged from 0.44 to 0.84, and McDonald's ω_t ranged from 0.56 to 0.85.

An adapted version of the *Pain Solutions Questionnaire* (PaSol; de Vlieger et al., 2006) was used to assess participants' acceptance of their condition across four subscales: solving the condition, belief in a solution, meaningfulness of life despite the condition, and acceptance of the insolubility

of the condition. Its 14 items are scored on a 7-point Likert scale. At the three time points, Cronbach's α for the subscales ranged from 0.82 to 0.96 and McDonald's ω_t ranged from 0.82 to 0.95, except for belief in a solution at T1 ($\alpha = 0.75$; $\omega_t = 0.75$).

The *Harms and Unpleasant Experiences Survey* (HUES; Baer et al., 2021) was designed to measure unpleasant experiences during an MBI, perceived harm of the MBI, and support for any unpleasant experiences. Items are scored on Likert scales or are free-response questions.

In addition, participants reported on the frequency of their home practice during the intervention and follow-up phase in terms of formal practice (i.e., mindfulness exercises as practiced in group sessions) and informal practice (i.e., being mindful in daily life). At T3, participants evaluated the You-Mind app with regard to its usefulness for home practice, its user friendliness, and how frequently they used the app. To allow for an open-ended evaluation of mindfulness and the MBI, participants were asked to provide up to three positive and three negative aspects of mindfulness (e.g., "What did you experience as pleasurable/positive vs. unpleasurable/difficult? What did you experience as positive vs. negative effects?").

Semi-structured Interviews

To obtain a richer understanding of participants' experiences regarding the MBI, participants in Cohort 1 took part in semi-structured online interviews up to 2 weeks before the start and up to 4 weeks after the end of the MBI. The pre-intervention interviews included questions pertaining to participants' motivation and expectations about the MBI, their current quality of life, level of stress, and emotional state. The post-interviews included questions pertaining to participants' experience with the MBI, their current emotional state and quality of life, and their perceived influence of the MBI on their quality of life and their level of stress. The interview questions can be found in Online Resource 2. The pre-interviews were conducted by a PhD student, and the post-interviews were conducted by two Master's students.

Smartphone Application

A smartphone application (the You-Mind app) was developed in our lab to assist adolescents with their mindfulness practice. The app includes video material informing users about mindfulness and guided audio meditations. Additionally, the app can administer questionnaires at randomized intervals and inform users of new questionnaires via smartphone notifications. Before the first assessment (T1), participants downloaded the application on their smartphones from the app store. If participants experienced technical difficulties, a researcher provided assistance via email. Participants continued to have access to the You-Mind app after the end of the study. During the study period (until after T3), the You-Mind app logged usage data from participants, including starting times, visited audio and video materials, and app error logging.

Unfortunately, there were some technical difficulties with the You-Mind app during the study, resulting in the dropout of one participant due to recurring app malfunctioning. Additionally, follow-up PM data ($n = 3$), ESM T2 ($n = 6$), and/or ESM T3 data ($n = 9$) went missing for some participants of Cohort 1 and one participant of Cohort 2. As a result, seven participants had to be excluded from analyses ($n = 6$ for ESM data, $n = 1$ for PM data) because the required minimal compliance rate was not reached.

Data Analyses

Methods of analysis were preregistered and submitted for publication in a protocol paper prior to data collection. We used multilevel models with a restricted maximum likelihood estimator for all outcomes because these models account for the sampling hierarchy and are well suited to handle missing data (i.e., all observed data points can be included). The protocol paper stated that the full maximum likelihood estimator would be used for model fitting. However, this estimator produces biased variance estimates, especially in small samples, like in the present study (Hoffman, 2015). Therefore, the restricted maximum likelihood estimator was used. Models were fit with the lme4 package (version 1.1–31; Bates et al., 2015) in R (version 4.1.1; R Core Team, 2022) and all outcome variables were standardized prior to analyses. Random effect parameters for each outcome were selected following a top-down process of model selection, leading to different random effect parameters (random slope or random intercept models) across outcomes. Following recommendations in the literature (Barr et al., 2013), starting from a maximal model, we dropped the random intercept for group in a first step and random slopes with the smallest variance in a second step until non-convergence and singularity issues were resolved. Once these issues were addressed, the model including the random slope with the highest variance was selected. Random intercepts and slopes were allowed to covary.

Assumptions of homoscedasticity and normality of level 1 and level 2 residuals were checked using residual plots, quantile–quantile plots, and density plots, respectively. As violations of the normality or homoscedasticity assumption were observed for all outcomes, 95% wild bootstrapping confidence intervals (CIs) were calculated using the R package lmeresampler (version 0.2.4; Loy & Korobova, 2023). In contrast to parametric bootstrapping, wild bootstrapping does not require distributional assumptions on the error terms nor homoscedasticity and outperforms other

bootstrapping methods for inferential statistics in multilevel data (Modugno & Giannerini, 2015) and therefore allows for robust inference in case of assumption violations. For comparison, *t*-tests with Satterthwaite degrees of freedom approximations and corresponding *p*-values computed using the lmerTest package (Kuznetsova et al., 2017) are reported in tables alongside wild bootstrapping CIs. Multiple testing correction using the false discovery rate (Benjamini & Hochberg, 1995) was applied to all *p*-values of models estimating secondary outcomes but could not be applied to bootstrapping CIs as there currently is no procedure to apply the false discovery rate to bootstrapping CIs. Marginal R^2 (variance explained by fixed effects) and conditional R^2 (variance explained by fixed and random effects) were calculated based on Nakagawa and Schielzeth (2013).

For the PM, a piecewise model for intercept/slope discontinuity (Hoffman, 2015), the deviation slope model, was applied to test the effects of the MBI on emotional distress and secondary outcomes. This model was specified as:

$$Y_{ijk} = \beta_{0jk} + \beta_{1j} * Time_{ijk} + \beta_{2j} * InterceptMBI_{ijk} + \beta_{3j} * SlopeMBI_{ijk} + \beta_{4j} * InterceptFU_{ijk} + \beta_{5j} * SlopeFU_{ijk} + \beta_{6j} * cohort_k + e_{ijk}$$

Y_{ijk} (outcome measure of participant j of group k at time point i) is modeled as a function of the intercept (β_{0j}), a continuous slope coefficient across all phases (β_{1j}), an intercept for the change between the end of baseline and the start of the intervention phase (β_{2j}), a second slope coefficient for the intervention phase (β_{3j}), another intercept for the change between the end of the intervention and the start of the follow-up phase (β_{4j}), and a slope coefficient for the follow-up phase (β_{5j}), controlling for covariate cohort. Intercepts β_{2j} and β_{4j} were dummy-coded. This model allows us to test the difference in change across phases because the slope coefficients β_{3j} and β_{5j} are now interpreted as incremental to the continuous linear time slope β_{1j} and, in the case of β_{5j}, to the slope for the intervention phase β_{3j}. The slope coefficient β_{1j} describes specifically the change during the baseline phase after controlling for all other fixed effects.

The direct slope model, was applied to test change in outcomes for each phase individually, as mentioned in our protocol (Kock et al., 2021). The model was specified as:

$$Y_{ijk} = \beta_{0jk} + \beta_{1j} * SlopeBL_{ijk} + \beta_{2j} * InterceptMBI_{ijk} + \beta_{3j} * SlopeMBI_{ijk} + \beta_{4j} * InterceptFU_{ijk} + \beta_{5j} * SlopeFU_{ijk} + \beta_{6j} * cohort_k + e_{ijk}$$

In the second model, all fixed effects remain the same compared to the previous model except for the slope coefficient β_{1j}, which now represents the slope during the baseline phase. The other two slope coefficients β_{3j} and β_{5j} now capture the change specifically during the intervention and follow-up phases, respectively, and are not incremental to the change in previous phases.

For the ESM and SRQs, a piecewise multilevel model (van der Gucht et al., 2019) was applied to test the effects of the MBI on primary and secondary outcomes. The model was specified as:

$$Y_{ijk} = \beta_{0jk} + \beta_{1j} * T2_{ijk} + \beta_{2j} * T3_{ijk} + \beta_{4j} * cohort_k + e_{ijk}$$

Change in outcome measure Y_{ijk} of participant j of group k at time point i is modeled using a discontinuous trajectory with a slope coefficient for T2 (β_{1j}) and a slope coefficient for T3 (β_{2j}), controlling for the covariate cohort. T2 and T3 were dummy-coded variables reflecting post-assessment and follow-up assessment time points, respectively.

Secondary outcomes measured using ESM or SRQs, for which a significant effect of the MBI was found, were included in exploratory mediation analyses. Lower level time-lagged mediation models (van der Gucht et al., 2019) were used to test whether changes in secondary outcomes (i.e., mediators) explain subsequent changes in primary outcomes. All mediation models were random intercept-only models. The model was specified as:

$$M_{ij} = d_j^M + a_j * Mchange_{ij} + e_{ij}^M$$

$$Y_{ij} = d_j^Y + b_j * M_{(i-1)j} + c\prime_j * Time_{ij} + g_j * cohort_j + e_{ij}^Y$$

Mediator M_{ij} of participant j at time point i is modelled with the dummy-coded variable *M* change (coded as 0, 1, 1 for T1, T2, and T3, respectively). Outcome Y_{ij} is modelled as a function of the mediator at the previous time point $t-1$ and the dummy-coded variable time (coded as 0, 0, 1 for T1, T2, and T3, respectively), controlling for the covariate cohort. The coefficient a_j describes a linear change in the mediator from T1 to T2 (a-path), while the coefficient b_j represents the time-varying lagged association between the mediator and the outcome, controlling for the effect of time on the outcome. The indirect effect was estimated as the cross-product of a_j and b_j coefficients, and the significance of the indirect effect was tested using CIs generated based on the distribution of the product method implemented in the R package RMediation (Tofighi & MacKinnon, 2011).

Frequencies were calculated for Likert-scale ratings of unpleasant experiences and perceived harm associated with the MBI, as measured by SRQs. Open-ended responses regarding these experiences were described and summarized.

Interviews were audio-recorded and transcribed verbatim. Only data from participants who took part in both pre- and post-intervention interviews was included in the analysis. A thematic analysis, following Braun and Clarke (2006), using the software NVivo was conducted. Interviews were coded

following a theoretical approach guided by the research questions of this pilot study and the conceptual framework of quality of life developed by Schalock et al. (2008). Based on the identified codes, overarching themes were searched, revisited, and defined. From the codes and themes, an overview of participants' experiences within and across themes was created.

Results

Participant Flow

A flow diagram of the participant recruitment and retention process is displayed in Fig. 2. In total, 81.82% of participants completed the MBI. One participant dropped out during the T1 ESM assessment because of difficulties in finding a safe place to join the online MBI, and two participants dropped out during the baseline phase because of a stay at the revalidation center and difficulties in combining the study with school tasks. Only one participant dropped out during the MBI due to illness, and another participant completed the intervention but stopped the assessments during the intervention period because of difficulty in combining the MBI or the assessments with school tasks, respectively. Finally, one participant dropped out during the follow-up phase because the You-Mind app stopped working. The fact that only one participant discontinued the MBI suggests that the MBI was acceptable for most participants. Notably, participants reported problems with playing longer meditation audios on the You-Mind app, and as a result, stopped using the app for home practice. This suggests that app usage data does not reflect the actual level of home practice; and we therefore decided not to include the number of completed homework assignments as a covariate in the models, as it was mentioned in the protocol paper. Information on attendance at group sessions, adherence to home practice, and compliance rates for quantitative measurements can be found in Online Resources 3 and 4.

Descriptive Statistics

Means and standard deviations of all outcome variables for participants included in the analyses can be found in Online Resource 5 (Tables S5 and S6). With regard to symptom severity measured by the DASS-21, 61.90% of participants experienced moderate, severe, or extremely severe depressive symptoms and anxiety at T1. For stress, 28.57% of participants experienced at least moderate symptoms at T1. Symptoms improved at T2, with 38.89%, 55.56%, and 22.22% of participants reporting at least moderate depressive symptoms, anxiety, and stress, respectively. Symptom improvement was retained at T3 (see Online Resource 5, Table S7). According to quality of life measured by the Peds-QL, 38.10% of participants suffered from severe physical complaints and 71.43% suffered from severe psychosocial complaints due to their chronic health condition at T1. Psychosocial complaints improved at T2 and were retained at T3, with 55.56% suffering from severe psychosocial complaints due to their chronic health condition. However, physical complaints worsened slightly at T2 and were retained at T3, with 44.44% of participants suffering from severe physical complaints due to their chronic health condition.

Efficacy of MBI

PM Data

Two multilevel models, the deviation slope and the direct slope model, were applied to test the effect of the MBI on emotional distress and secondary outcomes. Fixed effect estimates of deviation slope models estimating primary outcomes are displayed in Table 2. Compared to the change in the previous phase, emotional distress significantly increased at the beginning of the intervention ($b = 0.26$, 95% CI [0.01, 0.57]) and significantly decreased at the beginning of the follow-up phase (T2; $b = -0.43$, 95% CI [−0.68, −0.18]). When looking at individual subscales, depressive feelings decreased at the beginning of the follow-up phase (T2; $b = -0.44$, 95% CI [−0.72, −0.21]) compared to the change in the intervention phase. Stress increased at the beginning of the intervention ($b = 0.35$, 95% CI [0.12, 0.61]) and decreased at the beginning of the follow-up phase (T2; $b = -0.36$, 95% CI [−0.63, −0.11]) compared to the change in the previous phase. Anxious feelings did not change. Fixed effect estimates for direct slope models estimating primary outcomes and for deviation and direct slope models estimating secondary outcomes can be found in Online Resource 6 (Tables S8–S10). Estimates of random effects for primary and secondary outcomes for both models can be found in Online Resource 6 (Tables S11–S14).

ESM Data

Piecewise multilevel models were used to test the effect of the MBI on primary and secondary outcomes. Table 3 displays fixed effect estimates for emotional distress. Contrary to our hypotheses, emotional distress increased from T1 to T2 ($b = 0.58$, 95% CI [0.04, 1.30]). When looking at individual subscales, stress increased from T1 to T2 ($b = 0.77$, 95% CI [0.24, 1.43]). Depressive and anxious feelings did not change significantly. Fixed effect estimates for secondary outcomes and random effects estimates for primary and secondary outcomes can be found in Online Resource 5 (Tables S15–S17).

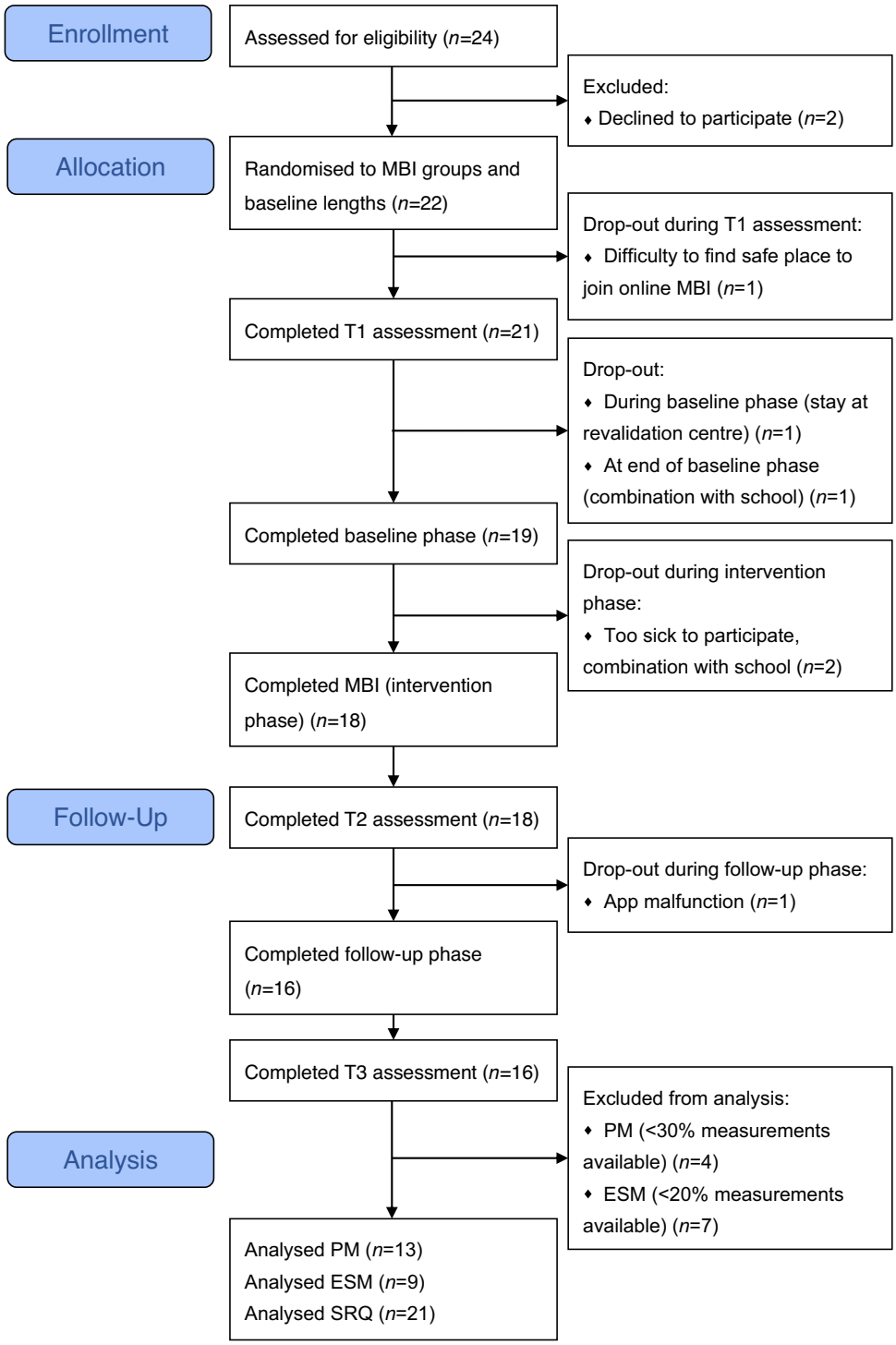


Fig. 2 Participant flow

SRQ Data

Similar piecewise multilevel models were used to test effects on all primary and secondary outcomes measured with validated SRQs. Table 4 presents fixed effects estimates for primary outcomes. There was no significant change in emotional distress nor quality of life at T2 or T3. These findings differ from PM and ESM data, likely because the SRQs were administered only once per time point using validated measures, whereas the PM and ESM used multiple single-item assessments. Fixed effects estimates for all secondary outcomes and random effects estimates for primary and secondary outcomes can be found in Online Resource 5 (Tables S18–S21). At T3, participants were asked to name three positive and negative

Table 2 Fixed effects of multilevel deviation slope models estimating primary outcomes (PM data)

Outcome	Emotional distress			Depressive		
	Est. (SE)	*t* (*df*)	Boot. CI	Est. (SE)	*t* (*df*)	Boot. CI
Inter.	−0.55 (0.25)	−2.24 (13.07)*	[−0.92, −0.05]*	−0.33 (0.25)	−1.32 (14.00)	[−0.79, 0.12]
Time	0.01 (0.01)	1.44 (75.33)	[0.00, 0.02]	0.00 (0.01)	0.48 (60.02)	[−0.01, 0.02]
Inter. MBI	0.26 (0.20)	1.32 (27.10)	[0.01, 0.57]*	0.32 (0.27)	1.22 (12.89)	[−0.12, 0.90]
Slope MBI	0.00 (0.01)	0.31 (335.90)	[−0.04, 0.05]	0.00 (0.02)	−0.21 (17.34)	[−0.06, 0.04]
Inter. FU	−0.43 (0.20)	−2.15 (34.50)*	[−0.68, −0.18]*	−0.44 (0.20)	−2.23 (19.10)*	[−0.72, −0.21]*
Slope FU	0.00 (0.01)	0.44 (209.48)	[−0.03, 0.04]	0.02 (0.01)	2.01 (171.91)*	[−0.01, 0.04]
Cohort	0.41 (0.29)	1.39 (5.64)	[−0.27, 1.02]	0.26 (0.31)	0.81 (9.20)	[−0.45, 0.86]
Outcome	**Anxious**			**Stressed**		
	Est. (SE)	***t* (*df*)**	**Boot. CI**	**Est. (SE)**	***t* (*df*)**	**Boot. CI**
Inter.	−0.36 (0.27)	−1.34 (13.35)	[−0.81, 0.15]	−0.56 (0.22)	−2.61 (12.26)*	[−0.93, −0.15]*
Time	0.00 (0.01)	0.34 (42.31)	[−0.01, 0.01]	0.01 (0.01)	1.69 (72.38)	[−0.01, 0.03]
Inter. MBI	0.19 (0.15)	1.24 (457.21)	[−0.03, 0.44]	0.35 (0.21)	1.65 (29.10)	[0.12, 0.61]*
Slope MBI	0.01 (0.01)	0.98 (346.60)	[−0.03, 0.06]	0.00 (0.01)	0.23 (356.05)	[−0.04, 0.04]
Inter. FU	−0.27 (0.21)	−1.30 (54.48)	[−0.76, 0.20]	−0.36 (0.22)	−1.64 (41.07)	[−0.63, −0.11]*
Slope FU	0.01 (0.01)	0.85 (184.02)	[−0.02, 0.03]	−0.01 (0.01)	−0.74 (210.79)	[−0.04, 0.02]
Cohort	0.23 (0.35)	0.65 (9.12)	[−0.47, 0.82]	0.27 (0.30)	0.92 (8.21)	[−0.38, 0.84]

Est., estimate; *SE*, standard error; *df*, degrees of freedom; *Boot. CI*, 95% wild bootstrapping confidence interval; *Inter*., intercept; *FU*, follow-up
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table 3 Fixed effects of multilevel models estimating primary outcomes (ESM data)

Outcome	Emotional distress			Depressive		
	Est. (SE)	*t* (*df*)	Boot. CI	Est. (SE)	*t* (*df*)	Boot. CI
Intercept	−0.31 (0.43)	−0.72 (1.69)	[−0.76, 0.21]	−0.27 (0.18)	−1.49 (7.62)	[−0.63, 0.08]
T2	0.58 (0.30)	1.90 (7.35)	[0.04, 1.30]*	0.24 (0.28)	0.88 (6.21)	[−0.29, 0.93]
T3	0.48 (0.62)	0.78 (3.82)	[−1.01, 1.93]	0.30 (0.44)	0.67 (4.24)	[−0.64, 1.08]
Cohort	0.00 (0.60)	0.00 (1.61)	[−0.64, 0.85]	0.38 (0.26)	1.49 (7.05)	[−0.16, 0.89]
Outcome	**Anxious**			**Stressed**		
	Est. (SE)	***t* (*df*)**	**Boot. CI**	**Est. (SE)**	***t* (*df*)**	**Boot. CI**
Intercept	−0.22 (0.26)	−0.84 (7.56)	[−0.87, 0.34]	−0.34 (0.24)	−1.4 (1.44)	[−0.64, −0.01]*
T2	0.18 (0.29)	0.61 (6.23)	[−0.36, 0.92]	0.77 (0.32)	2.42 (7.54)*	[0.24, 1.43]*
T3	0.29 (0.68)	0.42 (3.98)	[−1.22, 1.79]	0.41 (0.69)	0.59 (3.47)	[−0.87, 1.82]
Cohort	0.15 (0.37)	0.41 (6.14)	[−0.49, 1.13]	0.18 (0.34)	0.53 (1.44)	[−0.22, 0.67]

Est., estimate; *SE*, standard error; *df*, degrees of freedom; *Boot. CI*, 95% wild bootstrapping confidence interval
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

aspects of mindfulness meditation. A detailed overview of themes can be found in Online Resource 8.

Mediation Analyses

Mediation analyses were performed for secondary outcomes (ESM and SRQ data) for which a significant change at T2 or T3 was found. Table 5 presents fixed effects of the mediated pathway of secondary outcomes on emotional distress and quality of life, and the 95% confidence interval of the indirect effect. For ESM data, the indirect effect for repetitive negative thinking was small but significant ($b = 0.01$, 95% CI [0.01, 0.02]) meaning that the increase in repetitive negative thinking from T1 to T2 mediated the increase in emotional distress from T2 to T3. However, given the small effect size, the clinical relevance of this indirect effect is questionable. For SRQ data, the indirect effect for self-coldness was significant ($b = -0.24$, 95% CI [−0.52, −0.04]) meaning that the decrease in self-coldness from T1 to T2 mediated the reduction in emotional distress from T2 to T3. There was no significant indirect effect for overall self-compassion.

Table 4 Fixed effects of multilevel models estimating primary outcomes (SRQ data)

Outcome	Emotional distress			Depressive		
	Est. (SE)	***t* (*df*)**	**Boot. CI**	**Est. (SE)**	***t* (*df*)**	**Boot. CI**
Intercept	−0.03 (0.25)	−0.10 (27.11)	[−0.54, 0.56]	−0.05 (0.25)	−0.20 (25.08)	[−0.60, 0.54]
T2	−0.24 (0.22)	−1.10 (18.58)	[−0.70, 0.19]	−0.22 (0.22)	−1.01 (25.74)	[−0.68, 0.23]
T3	−0.16 (0.27)	−0.59 (22.07)	[−0.79, 0.47]	−0.28 (0.22)	−1.30 (17.83)	[−0.74, 0.18]
Cohort	0.34 (0.39)	0.88 (19.63)	[−0.36, 1.02]	0.51 (0.40)	1.28 (19.20)	[−0.16, 1.11]
Outcome	**Anxious**			**Stressed**		
	Est. (SE)	***t* (*df*)**	**Boot. CI**	**Est. (SE)**	***t* (*df*)**	**Boot. CI**
Intercept	−0.01 (0.23)	−0.05 (29.81)	[−0.46, 0.47]	−0.01 (0.26)	−0.06 (26.49)	[−0.56, 0.62]
T2	−0.25 (0.24)	−1.05 (18.97)	[−0.72, 0.22]	−0.15 (0.21)	−0.74 (18.53)	[−0.60, 0.23]
T3	−0.08 (0.32)	−0.24 (20.36)	[−0.79, 0.66]	−0.08 (0.24)	−0.31 (23.21)	[−0.64, 0.51]
Cohort	0.29 (0.34)	0.84 (19.21)	[−0.50, 1.03]	0.15 (0.40)	0.37 (19.56)	[−0.61, 0.84]
Outcome	**Physical quality of life**			**Psychosocial quality of life**		
	Est. (SE)	***t* (*df*)**	**Boot. CI**	**Est. (SE)**	***t* (*df*)**	**Boot. CI**
Intercept	0.17 (0.30)	0.58 (19.33)	[−0.36, 0.67]	0.21 (0.25)	0.82 (25.17)	[−0.28, 0.72]
T2	−0.13 (0.13)	−1.01 (23.06)	[−0.46, 0.12]	0.07 (0.19)	0.38 (33.01)	[−0.34, 0.49]
T3	−0.17 (0.11)	−1.52 (15.90)	[−0.43, 0.03]	0.17 (0.20)	0.85 (33.31)	[−0.26, 0.59]
Cohort	−0.51 (0.52)	−0.98 (18.53)	[−1.64, 0.55]	−0.81 (0.41)	−2.00 (18.33)	[−1.52, −0.10]*

Est., estimate; *SE*, standard error; *df*, degrees of freedom; *Boot. CI*, 95% wild bootstrapping confidence interval

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table 5 Estimates of multilevel coefficients (SE) and confidence intervals for mediation analyses of secondary outcomes on the associations between time and primary outcomes (ESM and SRQ data)

	a	**b**	**ab [95% CI]**	**c**
ESM data				
Emotional distress				
RNT	0.57 (0.08)***	0.02 (0.00)***	0.01 (0.00) [0.01, 0.02]*	0.06 (0.13)
SRQ data				
Emotional distress				
NA suppression	−0.50 (0.22)*	0.05 (0.19)	−0.02 (0.10) [−0.24, 0.18]	−0.27 (0.25)
Self-compassion	0.30 (0.10)**	−0.66 (0.34)	−0.20 (0.13) [−0.48, 0.00]	−0.20 (0.27)
Self-coldness (rev)	0.53 (0.15)***	−0.46 (0.19)*	−0.24 (0.12) [−0.52, −0.04]*	−0.24 (0.25)
Solving condition	0.61 (0.23)*	0.20 (0.19)	0.12 (0.13) [−0.10, 0.42]	−0.29 (0.24)
Meaning of life	0.30 (0.21)	−0.05 (0.23)	−0.02 (0.09) [−0.21, 0.15]	−0.26 (0.25)
Quality of life				
NA suppression	−0.50 (0.22)*	−0.13 (0.12)	0.06 (0.07) [−0.06, 0.23]	0.14 (0.13)
Self-compassion	0.30 (0.10)**	0.28 (0.23)	0.08 (0.08) [−0.05, 0.26]	0.10 (0.14)
Self-coldness (rev)	0.53 (0.15)***	0.22 (0.14)	0.12 (0.08) [−0.03, 0.30]	0.11 (0.14)
Solving condition	0.61 (0.23)*	−0.21 (0.14)	−0.13 (0.10) [−0.36, 0.04]	0.17 (0.12)
Meaning of life	0.30 (0.21)	−0.09 (0.17)	−0.03 (0.07) [−0.18, 0.09]	0.11 (0.13)

a, change in mediator from T1 to T2; *b*, effect of mediator on primary outcome (emotional distress; quality of life); *ab,* indirect effect; *c*, direct effect; *RNT*, repetitive negative thinking; *NA*, negative affect; *rev*, reverse coded

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Interview Data

Out of the 15 participants in Cohort 1, 10 participants completed interviews before and after the MBI and were therefore included in the analyses. In the analysis, the following four main themes were identified: (1) perceived quality of life before the MBI, (2) expectations regarding the MBI, (3) positive and negative aspects of the MBI, and (4) experienced effects of the MBI. Expectations and experienced effects were structured following the conceptual framework of quality of life developed by Schalock et al. (2008).

Theme 1. Perceived Quality of Life Before the MBI

During the interviews, participants described how they perceive their quality of life before the MBI. Overall, participants were rather satisfied with their quality of life, rating it on average 7.5 out of 10. Several life domains contributed positively to participants' quality of life, but these life domains differed across participants. Two participants mentioned that their personal development positively impacted their quality of life because they aspired to and achieved good results at school. One participant highlighted his ability to strive for his personal goals and succeed despite his doctor's negative expectations that he would not be able to succeed at some of his goals. The fact that the participant managed to succeed improved his quality of life.

> They used to always say: 'He's not going to be able to do this and he's not going to be able to do that'. For the past four years, every time I prove to doctors what I can do or what they say I can't do, so to speak. I think that's just super cool to show that you don't always have to be negative about someone. That you should just say: 'You might not be able to do that' or 'You can learn that'. Because I learned it all too. (Participant 9)

For two participants, self-determination was an important factor for their quality of life. Their high independence compared to their classmates, especially their ability to make decisions for themselves and to act upon their decisions, improved their quality of life. Six participants considered their interpersonal relationships with family and friends as an important factor that contributed to their quality of life. They explicitly expressed their gratitude toward their family and friends for being a part of their lives.

> Yes, despite the fact that I have been ill and have been through so much already, I am still happy that I have finally found good friends, parents I can turn to, certainly my godfather too. (Participant 13)

Three participants reported that their emotional well-being positively contributed to their quality of life. Specifically, they were satisfied with how their life was progressing and with the tasks they could already do. One participant mentioned that his emotional well-being was better at the time of the interview compared to last year, which also positively contributed to his quality of life. With regard to physical well-being, two participants reported that they enjoyed sports and that engaging in sports improved their quality of life. Two other participants described how they perceived their health condition in relation to others with the same condition. Specifically, they expressed their gratitude for being able to engage in more activities compared to other adolescents suffering from the same condition.

> I know I could be much worse off. Because I also come into contact a lot with people who have the same thing but have much worse living conditions or can't do anything so to speak. I'm actually lucky that I can do things. (Participant 9)

Finally, one participant stated that her material well-being, specifically her living environment and housing conditions, contributed to her quality of life.

There were also several life domains that negatively influenced participants' quality of life, namely personal development, interpersonal relationships, emotional well-being, and physical well-being. Two participants indicated that certain aspects of personal development negatively impacted their quality of life. One participant reported that the lack of social skills prevents her from interacting with others, which in turn decreases her quality of life. For another participant, the inability to perform certain activities because of his chronic condition sometimes generated stress or anger, which negatively contributed to his quality of life.

> If I know that because of my disability I can't do that but I want to and that's so, because I do want to do quite a lot in my life or … everything that comes my way I want to try anyways but it's very difficult to do that sometimes and then that brings stress or I get a bit angry about that. If that fails then, sometimes I can accept that but sometimes not. (Participant 9)

In the domain of interpersonal relationships, three participants mentioned that interactions with others sometimes negatively impacted their quality of life. The reason for the negative impact was the content, e.g., the death of a loved one, the person they are interacting with, e.g., friends pretending to be different than they are, or the type of conversation, e.g., an argument with their parents. Importantly, most participants reported that their emotional well-being negatively influenced their quality of life. Seven out of 10 participants perceived their self-image to negatively impact their quality of life, mainly because of frequently feeling insecure. One participant mentioned having high expectations for herself or "setting the bar high for herself." Moreover, seven participants reported experiencing stress related to school performance; three participants experienced stress related to interpersonal relationships and four participants reported experiencing stress related to their chronic condition. Stress related to the chronic condition was caused by the need to plan food intake or to pay attention to sugar values for two participants with diabetes, whereas another participant reported being stressed or angry about his chronic condition limiting what he was able to do (see quote of Participant 9 above).

> It's often with food that I have to pay attention, so then I'm already figuring out in advance this has to go with

it, that has to go with it, so yes that does stress me out, yes. (Participant 2)

In the domain of physical well-being, two participants reported that their chronic condition negatively impacted their quality of life. One participant stated that her headache drained her energy and affected her mood, which caused her to be easily irritated or angry. Hence, her headaches limited her engagement in activities like meeting friends or participation in society.

Now I also notice, during the year, that I can also do a lot less, for example that was already last year, when I couldn't go on the Paris trip and I really regretted that. Or when all the people my age go to a party ... I have to miss all that too. (Participant 7)

Another participant first reported his chronic condition (diabetes) to negatively impact his quality of life but also recognized that other chronic conditions have a larger impact on quality of life, thereby putting the impact of his diabetes into perspective.

Some things could be better like that disease but I can live with it because it is also not the worst disease there is. (Participant 11)

Theme 2. Expectations Regarding the MBI

Participants described several expectations relating to different factors of quality of life, namely personal development, interpersonal relationships, emotional well-being, and physical well-being. With respect to personal development, six participants expected that the MBI would help them to let go and find tranquility in their daily lives. Moreover, two participants were hoping that the MBI would allow them to better cope with negative emotions and thoughts.

Just finding a bit of peace. That I'm also no longer so stressed about everything and can just enjoy doing what I like and not start thinking in advance about things going wrong. (Participant 2)

One participant expected that the MBI would help her to become more aware of her experiences in the present moment as she is sometimes unable to identify her current feelings or thoughts.

I expect that I am more aware of: … 'Do I have stress now?' Because I feel that sometimes I do have some underlying stress but then I don't really realise, … now I actually have stress. (Participant 14)

Three participants expected an improvement in their interpersonal relationships following the MBI. Specifically, they were hoping to become calmer and friendlier when interacting with individuals in their environment, which in turn would motivate their interaction partners to also behave friendlier towards them.

Just because my father and my mother often catch me being brusque. Everyone actually catches me on that. And now, for example, if I am a bit more ... friendly or something, they start being friendly back to me and so on. (Participant 9)

With regard to emotional well-being, six participants expected that the MBI would help to improve their self-esteem, which some participants reported to be low before the MBI.

Yeah, I think my self-image that [the mindfulness training] is going to help too, that I'm going to trust myself more or something or ... that I don't see myself as someone bad or something. (Participant 9)

Another aspect of emotional well-being that many participants were hoping to improve was stress. Five participants expected that the MBI would help them reduce their stress levels or at least gain more control over their stress.

I hope it can lower my stress level a bit and yes ... if I have a difficult moment ... [if I] have an emotional moment or have negative thoughts that I can get rid of that because of what I have learnt or what I have seen at the training. (Participant 3)

Finally, three participants expected that the MBI would have a positive impact on the symptoms of their chronic condition or the way they were dealing with these symptoms.

Theme 3. Positive and Negative Aspects of the MBI

All 10 participants were satisfied with the MBI. When being asked about the best and worst aspects of the MBI, nine participants reported the group aspect as the most enjoyable aspect of the MBI. Specifically, participants enjoyed sharing experiences with other participants, meeting new people, and two participants appreciated the close relationship that was forming among the group members. Besides the group aspects, two participants mentioned specific mindfulness exercises they liked the most, namely the weather report and the pause button. Both are short exercises guiding the participant to become aware of and accept their experience in the present moment. One participant mentioned how the sharing of experiences with others made him aware of how the experiences of the other participants differed from his own and from each other.

Everyone experiences that [the exercises] differently then, … when we talked about it [the experience with

exercises] then it was different for everyone. (Participant 12)

The least enjoyable aspect of the MBI that participants mentioned during the interview is largely equivalent to the negative aspects mentioned in the questionnaire (see the previous section). Four participants perceived the length of the exercises as the worst aspect because it was difficult to stay focused on the exercises or because they noticed they were getting tired of the exercises. Other aspects perceived as least enjoyable were the late time point of the group sessions ($n = 3$) and the difficulty in combining the mindfulness home practice with their school tasks ($n = 2$).

Theme 4. Experienced Effects of the MBI

When looking at the overall effects of the MBI on quality of life, seven participants experienced an increase in quality of life, one participant experienced no change in quality of life, and two participants experienced a decrease in quality of life from before until after the MBI. The two participants who experienced a decrease in quality of life clarified that this decrease was caused by the COVID-19 pandemic and was unrelated to the MBI.

I would say about the same amount [of stress]. But of course that's also because of Covid and so on that I do have more stress now [after the MBI]. The mindfulness has really made sure that I have less stress and can be more relaxed. (Participant 14)

The other participant perceived herself as a social person. Her health problems, in combination with the COVID-19 related measures, limited her in her social activities, which is why she experienced a decrease in quality of life. Importantly, all participants reported that the MBI had a positive impact on various domains of their quality of life.

In the domain of personal development, four participants stated that they learned strategies to control their stress and regain inner peace during the MBI, such as doing mindfulness exercises.

If you're having a hard time for a while or something … then … for me anyway … Then I just go to that app and do an exercise for a while and then yeah, after that I'm happy again or I'm relaxed again and I can go on. (Participant 13)

Because in the beginning I actually get no control over that [stress] at all and now through certain techniques I actually do … for the most part. (Participant 7)

Another four participants mentioned that they were more aware of their emotions, thoughts, and sensations due to the MBI.

I am much more aware of the now though and not that I am really living into the future anymore. I am tremendously aware of what's going on right now... Because yes... Because yes… for all we know, I might just as well not wake up the next morning and my life will also be over so I am now much more aware of the things I do in a day and I am so grateful that I get to do things in a day. (Participant 3)

In the domain of self-determination, one participant learned to not give up and keep going, thanks to the MBI. A second participant learned to independently regulate her stress, whereas before the MBI, she needed her mother to calm her down.

I rather think, for example, that if I was under a lot of stress, I could do the exercise myself and that I didn't need my mum. Usually I tell her: 'I'm stressed' and then we go for a walk. And now I am more independent because I can do the exercises myself. (Participant 13)

Moreover, one participant stated that the MBI improved his ability to make difficult decisions because he learned to first take a pause before making the decision.

I think this mindfulness training has done some good for me, for example, when I have to make a choice. I used to walk around and think: 'What am I going to do now? Or what choice do I choose'. Whereas now I would be more still and think for 5 minutes: 'What are the advantages? What are the disadvantages? What is the best choice for me now?' (Participant 9)

In the domain of interpersonal relationships, five participants experienced an improvement in their relationships or their interactions with others after the MBI. More specifically, two participants reported that they reacted more calmly in discussions compared to before the MBI, two participants were less anxious and therefore could more easily interact with others, and one participant mentioned that they had more energy to meet with friends than before the MBI.

I do try to react more calmly in certain situations or so and then I can say that that has improved with it [the mindfulness training]. (Participant 12)

With regard to the domain of social inclusion, one participant experienced an improvement in her participation in society. She was able to engage in more activities outside her house, such as going to restaurants or shopping, compared to before the MBI.

Before mindfulness I was so before … I had no energy to do things or to meet up with people and I do notice now, now that I can set the bar a little less high and still have a little less stress, that I feel like doing real

things again. To start meeting up with friends more. (Participant 7)

In the domain of rights, one participant reported that, thanks to the MBI, he was able to deal with situations where he feels treated unfairly and could put these experiences into perspective.

All participants experienced an improvement in their emotional well-being after the MBI. For five participants, their self-image improved, and they were able to develop a more positive relationship with themselves after the MBI.

Yes, to actually say: 'Okay yes, this is who I am' and just leave it that way. And not always just looking for your perfections. (Participant 14)
In that moment, you can also look at yourself a little more positively because that was also one of the things that we learned in mindfulness, try to look at it gently and befriend it. (Participant 7)

Six participants reported that they learned to accept themselves more during the MBI.

I have already learnt to accept myself, but not yet in certain things and this is just about starting to come. I don't know why, but more and more I am starting to accept myself. (Participant 9)

All participants experienced an increase in tranquillity and relaxation in their lives and a reduction in stress and worry. The reductions in stress and worry either pertained to their whole life or were related to school performance in particular. One participant reported that the PM gave a wrong impression of her actual stress level, as the stress ratings suggest that her stress level did not change from the baseline phase to the end of the MBI. However, she emphasizes that her mindfulness practice helped her to reduce stress caused by pressure at school, which she did not experience during the baseline phase in August when she was on summer holidays.

I was always very stressed when it came to my schoolwork and through mindfulness I have really tried to get rid of that. If now something didn't work out on an evening, I am content with that. Because for once, it's okay not to have everything finished how it's scheduled. And through mindfulness, I have also learnt to plan better for school. That I take my moments of rest much more so that I can do a mindfulness exercise or just relax. So that [mindfulness training] did affect me positively. (Participant 3)
When I look at the app, […] when the question comes up: 'How much stress do you have at the moment?' I still sit at the same level as in August [comment: during the baseline phase]. But... we have a lot of pressure from school so if I had to register that stress, I was looking mainly at school. Because outside school I actually experience pretty much no stress. So that I gave a bit of a wrong impression there with the app too, that that stress hasn't evolved but I do notice that that stress has become a bit less because of mindfulness. [...] You won't see that with me if you compare the figures with the app. I think I gave a wrong picture because of that. (Participant 3)

Within the domain of physical well-being, three participants experienced an improvement in their health. One participant reported falling asleep more easily thanks to the mindfulness exercises. Two participants experienced a reduction in symptoms of their chronic condition after the MBI. For one participant, the MBI helped to reduce her stress level. Because her headaches are related to her stress levels, the frequency of her headaches also decreased.

Always when I am stressed, I also tend to suffer from a lot of headaches. So because I have and do these mindfulness exercises, that's reduced now, though. (Participant 3)

Another participant who suffered from diabetes experienced a reduction in her sugar values after practicing mindfulness. She also reported that her sugar values were particularly low after a period of frequent mindfulness practice. Notably, she attributed the improvements in her sugar values to the mindfulness practice.

If I had high [sugar] values, I would go to mindfulness to calm myself down and also give my body some rest and then I noticed that those high [sugar] values slowly went away. … I also had after the mindfulness training, after those 8 weeks, I also suddenly … by practicing really hard, I also had one week where my sugars were really super good. That I thought of: 'Could it be because of mindfulness now that I'm working on it so much?' I do think it [mindfulness] helps me. (Participant 3)

Finally, three participants reported that the MBI positively impacted their daily activities. After the MBI, participants would integrate moments of peace and tranquility into their daily life when needed, for example, by integrating mindfulness exercises into their daily schedule.

I think mindfulness has mostly taught, for me, to look for things that bring me peace. That did have a big impact on me. (Participant 12)

Safety

Throughout the study period, no adverse events were reported by participants or mindfulness trainers. The

majority of participants (66.67%) never or occasionally had unpleasant experiences during the MBI, while 33.33% reported having unpleasant experiences more often. Of those reporting any unpleasant experiences, 23.08% described them as not at all and 76.92% as somewhat upsetting. In total, 88.89% of participants reported the MBI as not at all harmful. Information on unpleasant experiences during the MBI can be found in Online Resource 7.

Discussion

This pilot study used a randomized staggered within-subjects design to investigate the effect of a four-session online MBI on emotional distress and quality of life, and to what extent it replicates across a sample of adolescents with various chronic conditions. Results showed different effects of the MBI on primary outcomes depending on the type of measurement (PM, ESM, or SRQ). For PM data, deviation slope models and direct slope models showed an acute increase in stress after the start of the MBI and an acute decrease in depressive feelings and stress after the end of the MBI that replicated across our participants with chronic conditions. The acute increase in stress after the start of the MBI might be explained by the timing of the MBI that coincided with the start of the school year. For several participants, this period was also an important transitioning phase to university. This explanation was supported by one participant during the post-MBI interview. She reported that the PM data did not accurately reflect her actual stress levels, as her mindfulness practice decreased her stress levels. However, this decreasing effect of the MBI is not visible in her reported stress levels because the pressure at school increased her stress levels after the start of the school year. Thus, it is likely that the observed increase in stress after the start of the MBI in our sample is mainly caused by the start of the new school year and/or transition to university, and only minimally, if at all, by the MBI.

The finding that depressive feelings and stress decrease after the end of the MBI is in line with our hypothesis. This reduction is consistent with two studies demonstrating that an MBI reduced depressive feelings but not anxiety in adolescents with chronic pain (Grazzi et al., 2022; Hesse et al., 2015). Moreover, one study reported a larger effect size for the effect of an MBI on depression compared to anxiety in children with chronic conditions (Andreotti et al., 2017). In contrast with our results, three studies showed a significant effect of an MBI only on anxiety and not depression in adolescents with chronic conditions (Lagor et al., 2013; Ruskin et al., 2017; Suc et al., 2022). The fact that we only found an effect after the end of the MBI, and not already at the start of or during the MBI, indicates that sufficient practice is required for the MBI to exert an effect on emotional distress in our sample of adolescents with chronic conditions. This finding supports the idea that mindfulness is a skill that needs to be developed through continued practice, as described in the theoretical underpinnings of MBIs and Buddhist contemplative traditions (Grossman, 2010).

For ESM data, we found an increase in stress from T1 to T2 that replicated across our participants with chronic conditions. Given that T2 assessments took place after the end of the MBI, this finding seems to contradict the acute decrease in stress after the end of the MBI we observed across our participants in PM data. However, the effect found in PM data describes an acute decrease from the end of the MBI until the start of the subsequent follow-up phase. In contrast, the effect found in ESM data demonstrates an increase in stress from T1 before the baseline phase until T2 at post-intervention. Hence, the increase in stress observed in ESM data at T2 might be explained by the timing of COVID-19 measures, which were introduced by the Belgian government at the time of T2 assessments for both cohorts. Given that a large proportion of our sample likely belonged to a COVID-19 risk group, they may have needed to adapt their everyday lives more and for a longer period than their peers to protect themselves from a COVID-19 infection. Apart from the fact that young people were generally more affected by mental health problems during the COVID-19 pandemic (Pierce et al., 2020), changes to everyday activities and loneliness predicted mental distress in young people during the pandemic (Rens et al., 2021). Thus, the measures against the COVID-19 pandemic and the resulting social isolation may have increased stress levels in our sample. In support, two participants mentioned in the post-MBI interviews that the COVID-19 pandemic increased their stress levels while mindfulness practice enabled them to deal with the increased stress in their lives. This suggests that the MBI acted as a buffer against the increasing stress caused by the COVID-19 pandemic, at least for some participants. Additionally, the increase in stress might be explained by the timing of the study, with T1 taking place during the summer holidays and T2 during the school year. It is therefore unlikely that the increase in stress from T1 to T2 we observed across participants in ESM data is caused by the MBI.

For SRQ data, there were no significant effects on emotional distress or quality of life across participants. This lack of effects on SRQ data may be explained by the smaller sample size than anticipated and the resulting low power for SRQ data specifically, as these were only assessed at three time points. As explained before, the COVID-19 pandemic and the resulting high work load in Belgian hospitals hampered participant recruitment for the second cohort. To prevent losing participants who had already agreed to take part, recruitment was stopped after several weeks of recruitment difficulties. Given the insufficient power for SRQ analyses,

we cannot make reliable conclusions regarding the effects of the MBI on emotional distress and quality of life in our sample based on SRQ data. Nevertheless, it remains important to interpret these non-significant findings within the broader context of previous research using SRQs to evaluate MBIs for adolescents or children with chronic conditions, as prior studies have also yielded mixed results. Several studies found no effect on quality of life (Ali et al., 2017; Chadi et al., 2016; Lagor et al., 2013; Suc et al., 2022) while two studies found an effect on quality of life (Ahola Kohut et al., 2020; van der Gucht et al., 2017). Similarly, several uncontrolled studies and RCTs found no effect on depression, anxiety, or stress (Ahola Kohut et al., 2020; Chadi et al., 2016; Freedenberg et al., 2017; Malboeuf-Hurtubise et al., 2016; Ruskin et al., 2017; Young et al., 2022), while others found an effect on at least one of these outcomes (Ali et al., 2017; Andreotti et al., 2017; Chadi et al., 2019; Grazzi et al., 2022; Hesse et al., 2015; Lagor et al., 2013; Suc et al., 2022; van der Gucht et al., 2017). A discussion of secondary outcomes and mediation analyses is provided in Online Resource 9.

The results suggest that the MBI was perceived as acceptable (in terms of retention and adherence) and safe by our participants. Only one participant dropped out of the MBI, while five participants dropped out before or after the MBI or only dropped out of the research part, while still completing the MBI, indicating that drop-out was related to the burden of measurements rather than the MBI. Reasons for drop-out were associated with the MBI for three participants (e.g., difficulty to follow the MBI), while three participants dropped out for reasons unrelated to the MBI (e.g., stay at revalidation center, burden of completing questionnaires). The amount of mindfulness home practice is comparable to prior studies on similar populations (Ahola Kohut et al., 2020; Chadi et al., 2016), although one study reported a longer average duration of home practice (Chadi et al., 2019). Session attendance was higher, and drop-out rates were similar compared to prior studies (Ahola Kohut et al., 2020; Chadi et al., 2019; Malboeuf-Hurtubise et al., 2016). In addition, reasons for drop-out were less often related to the MBI in our sample compared to prior studies, suggesting equal or even improved acceptability of the MBI (assuming that attendance and drop-out rate, in combination with reasons for drop-out, are indicators of acceptability; Sekhon et al., 2017). However, participants perceived the 2-hr online sessions as too long, and most participants preferred shorter meditations. Future MBIs should include shorter but more frequent group sessions to allow the complete MBI content to be delivered, especially if they are offered in an online format. With regard to safety, most participants rated the MBI as not at all harmful. Nevertheless, 72.22% of participants had unpleasant experiences related to their mindfulness meditation at least occasionally. The reported unpleasant experiences are in line with typical unpleasant experiences during MBIs (Britton et al., 2021). Given the scarcity of research on unpleasant experiences related to MBIs, especially in adolescents, future studies should determine whether unpleasant experiences occur at a higher rate in participants randomized to an MBI compared to the control group.

Limitations and Future Directions

The results of this pilot study should be interpreted in light of several limitations. First, our pilot study was not sufficiently powered to detect changes in SRQ outcomes because the pre-registered sample size was not reached. Reasons were the ongoing COVID-19 pandemic and the resulting pressure on hospital personnel, which interfered with recruitment for our pilot study, paired with general difficulties to reach adolescents with chronic conditions. Future studies should consider multi-site recruitment to reach adequate sample sizes. Second, our pilot study did not include a control group. This limitation was partially mitigated by using a randomized staggered within-subjects design, which allows for causal inference by comparing changes in outcomes during the intervention phase to those in the baseline phase within each participant. Internal validity was further strengthened by randomizing intervention start times and examining consistent change patterns across participants (Kratochwill & Levin, 2010). Nonetheless, we are unable to rule out non-specific effects of the MBI such as the group setting and attention from the mindfulness trainer. Larger studies including an active control group are necessary to gain greater confidence in the findings.

Third, most outcomes (ESM and PM data) were assessed using intensive longitudinal measurements. This methodology has several strengths, such as high ecological validity, reduced retrospective biases, and the ability to test changes across multiple time points (Palmier-Claus et al., 2011), which was a requirement for our study design. However, the methodology also has certain limitations: (a) higher burden for participants and, therefore, existence of missing data, often to a greater extent than in SRQ data; (b) use of (non-validated) single-item measures; and (c) reliance on self-report. To address the former two limitations, we additionally included SRQ measures of all outcomes. The fact that effects on several outcomes were only visible in PM or ESM data, but not in SRQ data, highlights the advantages of this methodology. Regarding the reliance on self-report, we aimed to include an objective measure of home practice based on log-in data of the You-Mind app. However, participants stated that they performed their home practice mostly outside of the You-Mind app due to technical difficulties with the application. Therefore, we decided not to analyze the log-in data as it did not reliably reflect home practice of participants. Additionally, technical issues with

the application led to data loss, including the drop-out of one participant and the exclusion of seven others from parts of the analyses. The exact cause of the data loss remains unclear, whether due to failed notification delivery, errors during data transfer, or server-related issues. Given that app malfunctions repeatedly affected the same participants, device-specific compatibility issues are suspected. Future research may want to ensure the reliability and cross-platform functionality of smartphone applications.

Fourth, compliance with regard to ESM and PM data was limited, which should be understood in the context of our sample of adolescents with chronic conditions. If anything, the lower amount of ESM and PM data likely weakened rather than strengthened the results. The chance of outliers impacting the effects is higher due to the limited compliance. Therefore, it is important to focus on overall patterns across participants rather than isolated, one-time findings from individual cases. Notably, the multilevel models used are explicitly equipped to deal with an unequal amount of data across participants and to handle missing data. Future research should explore more effective strategies for engaging adolescents in completing assessments, such as using smartphone applications to reach them directly, rather than relying on communication through their parents' email addresses. Fifth, the generalizability of our findings is limited by the small sample size, the age range, and the variety of chronic conditions represented in the sample. Hence, our findings cannot be generalized to children, younger adolescents, or (young) adults, nor to populations with chronic conditions not represented in this sample. Given these limitations, the findings of this pilot study should be considered exploratory and require replication in future studies with larger sample sizes. Sixth, interview and self-report data in this pilot study may have been subject to biases such as social desirability bias, recall bias, and interviewer bias that may have led to more positive perceptions of the MBI's effects by participants.

Seventh, the timing of our pilot study in the school year may have influenced our results as discussed previously. Other studies also reported issues related to timing within the school year, such as low adherence to MBI sessions due to the MBI taking place at the end of the school year. It will be important for future studies on adolescent populations to closely consider the timing in the school year and its potential impact on the study. With respect to timing, our results also should be interpreted while keeping the broader context of the COVID-19 pandemic in mind. The COVID-19-related measures introduced by the government and the rise in COVID-19 cases may have specifically affected our sample for several reasons. Young age was generally a risk factor for mental health problems during the pandemic (Pierce et al., 2020). In our sample, many participants may have been at high risk for severe COVID-19 infections, which may have further limited their social contacts and increased COVID-related anxiety and worry. Finally, the COVID-19 pandemic required us to offer the MBI online even though the intervention was not designed for an online format. Based on feedback from participants and mindfulness trainers, who described the 2-hr online sessions as too long and tiring, we recommend decreasing session length and increasing session frequency in future online MBIs for adolescents with chronic conditions. Despite these limitations, the findings of this pilot study add to the growing literature on MBIs for adolescents with chronic conditions by providing preliminary evidence of their acceptability, safety, and potential to reduce emotional distress in a sample with diverse chronic conditions. Additionally, this pilot study offers initial insights into the mechanisms underlying these interventions.

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Author Contribution Merle Kock: conceptualization, methodology, validation, formal analysis, investigation, data curation, writing—original draft preparation, visualization, project administration. Eline Van Hoecke: resources, writing—review and editing. Patrick Onghena: methodology, writing—review and editing. Stijn Vandevelde: methodology, writing—review and editing, supervision. Mieke Matthyssen: methodology, writing—review and editing, supervision. Peter Kuppens: methodology, writing—review and editing, supervision. Filip Raes: conceptualization, methodology, writing—review and editing, supervision. Katleen Van der Gucht: conceptualization, methodology, investigation, writing—review and editing, supervision, project administration, funding acquisition.

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Data Availability The full pseudo-anonymized dataset will be shared beginning 3 months and ending 5 years following publication of the results. Access will be granted to interested researchers for any type of analysis if they agree with the confidentiality rules agreed upon in this study. To gain access, contact the authors at merle.kock@kuleuven.be. The study protocol, statistical analysis plan, and analytical code will be shared via the following link beginning 3 months and ending 5 years following publication of the results:
https://clinicaltrials.gov/ct2/show/NCT04359563?term=katleen+van+der+gucht&draw=2&rank=3.

Declarations

Ethics Approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee Research UZ/KU Leuven (S63485, leading committee) and the Ethics Committee of Ghent University Hospital and Ghent University.

Informed Consent Informed consent to participate and publish their data was obtained from all individual participants (and their parents if participants were below the age of 18 years) included in the study.

Use of Artificial Intelligence AI was used for editing the manuscript to improve the English language.

Competing Interest PK and FR are members of the managing committee of the Leuven Mindfulness Consortium Philanthropic Project; FR receives payments for workshops and presentations related to mindfulness. The authors declare that they have no other competing interests.

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Authors and Affiliations

Merle Kock[1,2] · Eline Van Hoecke[4] · Patrick Onghena[5] · Stijn Vandevelde[6] · Mieke Matthyssen[6,7] · Peter Kuppens[2,5] · Filip Raes[1,3] · Katleen Van der Gucht[5,8]

✉ Merle Kock
merle.kock@kuleuven.be

Eline Van Hoecke
Eline.VanHoecke@uzgent.be

Patrick Onghena
patrick.onghena@kuleuven.be

Stijn Vandevelde
Stijn.Vandevelde@ugent.be

Mieke Matthyssen
mieke.matthyssen@ugent.be

Peter Kuppens
peter.kuppens@kuleuven.be

Filip Raes
filip.raes@kuleuven.be

Katleen Van der Gucht
K.B.H.VanDerGucht@tilburguniversity.edu

1 Centre for the Psychology of Learning and Experimental Psychopathology, KU Leuven, Leuven, Belgium

2 Leuven Mindfulness Consortium, KU Leuven, Leuven, Belgium

3 KU Leuven Child and Youth Institute, KU Leuven, Leuven, Belgium

4 Pediatric Psychology, Department of Pediatrics, Ghent University Hospital, Ghent, Belgium

5 Research Unit Methods, Individual and Cultural Differences, Affect and Social Behavior, KU Leuven, Leuven, Belgium

6 Department of Special Needs Education, Ghent University, Ghent, Belgium

7 Fondation Huoshen, Wavre, Belgium

8 Department of Developmental Psychology, Tilburg University, Tilburg, The Netherlands