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Yoga, Meditation and Mindfulness in pediatric oncology – A review of literature

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ABSTRACT

Purpose: Children and adolescents undergoing treatment for cancer are exposed to a wide variety of stressors both physical and mental. Not only adults but also children and adolescents increasingly practice yoga in a health-promoting manner and to cope with stressful situations.
Methods: A review of literature was conducted to present the current outcomes on yoga, meditation and mindfulness for children and adolescents who are affected by an oncological disease.
Results: Eight studies were identified that examined yoga treatment for children and adolescents with oncological diseases. Three studies were found on mindfulness in pediatric oncology. The studies summarized here suggest that yoga and mindfulness could help to improve quality of life, reduce fatigue, improve activity and fitness levels, improve sleep quality, increase appetite and decrease anxiety in various stages of the disease and its treatment. The reviewed studies showed that yoga and mindfulness-based interventions for children and adolescents with oncological illnesses are feasible in different settings and are well received.
Conclusions: The results of the studies suggest that yoga and mindfulness may help to support children and adolescents during and after oncological treatment. Based on the current body of evidence it is not possible to draw conclusions about the efficacy of yoga and mindfulness-based interventions in pediatric oncology patients. Research must meet this challenge to develop suitable designs to further and better investigate the effects of yoga and mindfulness in children and adolescents with oncological diseases.

1. Introduction

The practice of yoga, mindfulness and meditation are central parts of Mind-Body-Medicine (MBM). Interventions in this area of MBM include a combination of movements, breathing, relaxation and meditation. The ideas of MBM are based on the findings of physiological and psychological stress research and psycho-neuro-endocrino-immunology that demonstrate the connection between mind and body and consequently the relationship of chronic stress and immune system dysfunction [1,2]. As part of integrative medicine, MBM is a resource-oriented complement to conventional medicine with a salutogenic, health promoting focus [3–5].

Performed regularly, both yoga and meditation can help to regulate tension and encourage mindfulness. Through the strengthening and stretching of the muscles, as well as the loosening and stretching of the connective tissue and fasciae, yoga practice helps to coordinate body and breathing which promotes deep relaxation [6]. With the help of meditation, mindfulness can be created through awareness of the present or the current moment, which may help to consciously distance ourselves from worries that occupy our thoughts, to reduce stress and create relaxation and simultaneous recovery for mind and body [7].

Not only adults but also children and adolescents increasingly

Abbreviations: MBM, Mind-Body-Medicine.

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practice yoga in a health-promoting manner [5,8]. Some studies show the positive effect on physical and mental well-being of children [8,9]. There are some indications of positive influence on physiological parameter e.g. metabolism and heart rate variability [5]. Promising results can also be shown in terms of dealing with school stress [10,11]. Meditation practices among children and youth can improve attention and psychological functioning and reduce blood pressure [7] and has positive effects on mental health and pain management [5].

Children and adolescents undergoing treatment for cancer are exposed to a wide variety of stressors. Conventional forms of oncological therapy, such as chemotherapy, radiation therapy, surgical interventions and stem cell transplantation, are associated with psychological and physical stress [12,13]. Patients in pediatric oncology suffer from side effects such as fatigue, pain, anxiety, sleep disorders, restlessness, depression, nausea and vomiting, and hair loss [12]. This can place an incredible burden on the body and mind of those affected and may lead to a significant reduction in quality of life [13,14].

In 2017, Danhauer et al. published a review that focused on yoga therapy during cancer treatment in children and adults. Interventions that involved only meditation or larger cancer-recovery programs of yoga or mindfulness-based stress reduction were excluded. The authors could identify eight non-randomized and 13 randomized studies for adults. The results show that yoga therapy during cancer treatment can help to improve psychological outcomes, such as anxiety, depression and distress. On a physiological level, fatigue, sleep, and all together quality of life could also be improved [15]. The authors could identify only four studies with pediatric patients. All of them were non-randomized controlled studies. Therefore, the authors concluded that they could not find enough studies to evaluate the efficacy of yoga in pediatric oncology [15].

The philosophy of yoga combines mindfulness and meditation as two important elements of yoga in addition to yoga asana (body exercises) (see "eight components of Yoga" of “Yoga Sutras of Patanjali”). In practice, the distinction between the three elements of yoga exercises, mediation and mindfulness is often not made, which justifies our decision to include literature studies that have dealing with yoga, mindfulness and meditation in this review of literature. In the last few years there has been increasing research activity in the field of MBM in pediatric oncology. We hereby aim to close the gap by presenting the current outcomes on yoga, meditation and mindfulness for children and adolescents who are affected by an oncological disease and discussing needed direction for future research as well as implications for clinical practice.

2. Method

2.1. Literature search procedure

The literature search method chosen was undertaken to give a better overview of the existing literature on MBM/yoga/meditation and mindfulness in pediatric oncology. Because our initial review of the data revealed extensive heterogeneity of study designs and a lack of systematic empirical studies such as RCT, we chose to do a narrative review of literature instead of a systematic review. The first literature search took place between June 12 and June 23, 2018. From 07/21/20–07/31/20 a search was carried out again to update the results. The search strategy with the used search terms and Boolean Operators is presented in Table 1 using the database *PsycINFO* as an example. The search was carried out in the following databases: MEDLINE (PUBMED), PsycINFO, LIVIVO, EMBASE (OVID), Web of Science and Cochrane Library.

2.2. Inclusion criteria

2.2.1. Main aspects

Studies must have been published in English or German. There were no restrictions made regarding the publication date as the research field of yoga and mindfulness (meditation) especially in pediatrics is still very young. Only primary studies were included in the search results.

2.2.2. Types of interventions

All studies were included that carried out yoga and/or mindfulness (meditation) interventions on pediatric oncology patients.

2.2.3. Participants

We considered all yoga and/or mindfulness (meditation) intervention studies performed on children and adolescents with cancer (0–18 years). In exceptional cases, the age group was extended to young adults with a maximum age of 24 years, since the outcomes were examined at children, adolescents and/or young adults together [16,17]. Patients could be in any section of cancer treatment, whether recently diagnosed, current treatment, aftercare, or palliative care.

2.2.4. Study-designs

Since yoga and mindfulness interventions have only recently been used in pediatric oncology and the research circumstances with this clientele are often difficult, we decided to also include single-armed trials without randomization Fig. 1.

3. Results

3.1. Study characteristics

Eight studies could be identified that examined yoga treatment for children and adolescents with oncological diseases. In five of the studies [16,18–21] the yoga intervention took place during hospitalization, i.e. during the treatment with conventional methods like chemotherapy, radiation therapy, surgical interventions and stem cell transplants. In one study the yoga intervention took place during outpatient chemotherapy [22]. Two of the identified studies [23,24] looked at post-hospitalization yoga treatment. In the study by Hooke et al. [23] conventional therapies were ended at least 2 and at most 24 months before the start of the study. Wurz et al. [24] made no information in this regard.

A total of three studies were identified on the subject of mindfulness in pediatric oncology. The study by Ahmed et al. [25] used Mantram Meditation in an outpatient treatment setting for children undergoing Anti-ganglioside GD2 monoclonal antibody therapy. In the study by Malboeuf-Hurtubise et al. [26] mindfulness practices and meditation were used in a group setting for adolescents in different cancer treatment stages. The mindfulness-based intervention study by Van der Gucht et al. [17] carried out a group program based on *Mindfulness-Based Stress Reduction* (MBSR) and *Mindfulness-Based Cognitive Therapy* (MBCR) for adolescents and young adults who had completed acute medical treatment at least one month before enrollment in the study.

The implementation of the yoga interventions in the studies differed greatly. The interventions took place individually [18–22] or in groups [16,23,24] and with or without the accompaniment of a family member or friend. The structure and duration of the individual yoga classes as well as the time period and frequency were different. All instructors were trained yoga teachers with experience in teaching children.

The number of participants in the yoga and mindfulness studies varied between six and 49 people. In eight of the identified studies, the patients themselves were defined as participants. In three studies [16,20,21] parents/caregivers were also included in the measurement outcomes. The number of pediatric and adolescent patients with oncological diseases who participated in the studies ranged from six to 34 people.

To measure the effectiveness of the yoga and mindfulness interventions, questionnaires were used in all studies. In the study by Orsey et al. [20], physical activity was also measured with the help of an actical monitor and the patients were asked to keep an activity diary.

Table 1
Study characteristics/ subject characteristics.

Reference	Yoga intervention (y) / mindfulness intervention (m)	Sample size (n) (without dropouts)/ age	Type of neoplasm	Conventional treatment method	Treatment stage at the time of intervention
1. Acute Pain Relief After Mantram Meditation in Children With Neuroblastoma Undergoing Anti-GD2 Monoclonal Antibody Therapy. (Ahmed, Modak & Sequeira, 2014).	m	n = 34, age: 3–14	High-Risk-Neuroblastoma	Anti-ganglioside GD2 monoclonal antibody (anti-GD2 MoAb 3F8) therapy	Outpatient treatment. Intervention is carried out at the same time as conventional treatment method.
2. A pilot study to evaluate the feasibility of individualized yoga for inpatient children receiving intensive chemotherapy. (Diorio et al., 2015)	y	n = 11, age: 7–16	Leukemia/lymphoma (n = 8), Solid tumor (n = 1), Brain tumor (n = 1), Aplastic anemia (n = 1)	Chemotherapy (n = 5) Stem cell transplantation (n = 6)	During intensive chemotherapy or haematopoietic stem-cell-transplant.
3. Feasibility Study: The Effect of Therapeutic Yoga on Quality of Life in Children Hospitalized With Cancer. (Geyer, Lyons, Amazeen, Alishio & Cooks, 2011)	y	n = 6 + 4 parents/ caregivers, age: 5–19	Acute lymphoblastic leukemia (n = 2), Acute myoblastic leukemia (n = 1), Acute lymphoblastic leukemia status post-bone marrow transplant (n = 1), Ewing sarcoma (n = 1), Fancomi anemia status post-bone marrow transplant (n = 1)	No information on therapies during the intervention study	During hospitalization and conventional treatment
4. Effect of yoga on the symptoms response in pediatric brain tumor in-patients undergoing chemo and radio-therapy. (Govardhan et al., 2019)	y	n = 18, age: 6–18	Anaplastic ependymoma (n = 6), Medulloblastoma (n = 5), Atypical neurocytoma (n = 1), Glioma (n = 4), CNS Germ cell tumor (n = 1), Retinoblastoma (n = 1)	Chemotherapy + Radiotherapy (78%), Only Radiotherapy (22%)	Intervention was conducted within the hospital premises after the scheduled chemo or radiotherapy session.
5. Yoga for Children and Adolescents After Completing Cancer Treatment. (Hooke, Gilchrist, Foster, Langevin & Lee, 2016)	y	n = 13 (7 children, age: 6–12 & 6 adolescents, age: 13–17)	Leukemia/lymphoma (n = 5), Solid tumor (n = 2), Central Nervous System (CNS) tumor (n = 6)	Chemotherapy only (n = 5), Chemotherapy & radiation (n = 2), Chemotherapy & surgery (n = 2), Radiation only (n = 1), Surgery & radiation (n = 1), Surgery only (CNS) (n = 2)	Conventional treatment ended 2–24 months previously, outpatient.
6. A Mindfulness-Based Meditation Pilot Study: Lessons Learned on Acceptability and Feasibility in Adolescents with Cancer. (Malboeuf-Hurtubise et al., 2016)	m	n = 14, age: 11–18 Experimental group (EG; n = 7), Control group (CG; n = 7)	Leukemia (EG=50%, CG=57,1%) Kidney (EG=12,5%, CG=14,3%) Brain tumor (EG=12,5%, CG=0%) Bone (EG=12,5%, CG=14,3%) Melanoma (EG=12,5%, CG=0%) Ovarian (EG=0%, CG=14,3%)	No information	Cancer phase: Recent diagnosis (EG=%, CG=0%), Active treatment (EG=12,5%, CG=14,2%), Remission (EG=85,7%, CG=28,5%), Relapse (EG=0%, CG=14,2%), Cure (EG=0%, CG=42,8%)
7. Results of a Pilot Yoga Intervention to Improve Pediatric Cancer Patients' Quality of Life and Physical Activity and Parents' Well-being. (Orsey et al., 2017)	y	n = 20 patients + parents (3 children, age: 8–13 & 7 adolescents, age: 13–18)	Acute lymphoblastic leukemia (n = 9), Ewing's sarcoma (n = 1), Germ cell tumor (n = 1), Glioblastoma (n = 2), Hodkin's disease (n = 2), Histiocytic neoplasm (n = 1), Medulloblastoma (n = 1), Osteosarcoma (n = 2), Spindle cell sarcoma (n = 1)	"Active cancer treatment", not specified	During the treatment of the neoplasm/hospitalization
8. A feasibility study examining the impact of yoga on psychosocial health and symptoms in pediatric outpatients receiving chemotherapy. (Stein et al., 2019)	y y	n = 10, age: 10–18, age 10–12 (n = 2), age 13–15 (n = 6), age 16–18 (n = 2)	Solid tumor (n = 5), Brain tumor (n = 4), Leukemia or lymphoma (n = 1)	Chemotherapy (n = 10, 100%)	Intervention during outpatient chemotherapy

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Table 1 (*continued*)

Reference	Yoga intervention (y) / mindfulness intervention (m)	Sample size (n) (without dropouts)/ age	Type of neoplasm	Conventional treatment method	Treatment stage at the time of intervention
9. Peaceful Play Yoga: Serenity and Balance for Children With Cancer and Their Parents: (Thygeson, Hooke, Clapsaddle, Robbins & Moquist, 2010)		Cohort of children: n = 11, age: 6–12; Cohort of adolescents: n = 5, age: 13–18; Parents: n = 33	Acute lymphocytic leukemia (ALL; n = 4), Relapsed ALL (n = 2), Acute myeloid leukemia (n = 1), Solid tumor (n = 4), CNS tumor (n = 4), Sickle cell disease (n = 1)	Chemotherapy (n = 3); Treatment method of the rest not further specified.	Intervention during hospitalization. Reason for hospitalization: Chemotherapy, New diagnosis/relapse (n = 5), Side effects (n = 8)
10. A Mindfulness-Based Intervention for Adolescents and Young Adults After Cancer Treatment: Effects on Quality of Life, Emotional Distress, and Cognitive Vulnerability. (Van der Gucht et al., 2017)	m	n = 16, age 14–24	Hodgkin lymphoma (n = 3), Non-Hodgkin lymphoma (n = 1), Leukemia (n = 2), Osteosarcoma (n = 3), Synovial sarcoma (n = 1), Seminoma (n = 1), Carcinoma (n = 2), Neuroblastoma (n = 1), Brain tumor (n = 1), Aplastic anemia (n = 1)	Chemotherapy alone (n = 6), Radiotherapy plus surgery (n = 1), Chemotherapy plus surgery (n = 4), Chemotherapy, radiotherapy and surgery (n = 3), Chemotherapy, radiotherapy and stem cell transplant (n = 1), Chemotherapy, radiotherapy, surgery, and stem cell transplant (n = 1)	Participants had completed acute medical treatment at least one month before enrollment in the study.
11. The Feasibility and Benefits of a 12-Week Yoga Intervention for Pediatric Cancer Out-Patients. (Wurz, Chamorro-Vina, Guilcher, Schulte & Culos-Reed, 2014)	y	n = 8, age: 5–17	Osteosarcoma (n = 1), Lymphoma (n = 1), CNS-Tumor (n = 2), Acute lymphoblastic leukemia (n = 2), Chronic myeloid leukemia (n = 1), Multiple diagnosis (n = 1)	Chemotherapy, Surgery and Radiation	After hospitalization. No indication whether conventional therapy was taking place at the same time.

Hooke et al. [23] and Wurz et al. [24] also conducted physical fitness tests in their studies.

The study by Ahmed et al. [25] also assessed the heart rate as a physical parameter. Some studies also collected qualitative data [18,19,21]. An overview of the individual study characteristics can be found in Table 1. Exact information on the intervention characteristics with details of the outcomes, measurement methods and results is shown in Table 2.

3.2. Quality characteristics

None of the identified yoga intervention studies used randomization. In the mindfulness-based intervention by Malboeuf-Hurtubise [26] randomization was planned but slow recruitment and low numbers of participants made randomization impossible. The mindfulness-interventions by Ahmed et al. [25] and Van der Gucht et al. [17] also did not use randomization. An ethical vote was obtained in all studies. Ahmed et al. [25] and Govardhan et al. [19] did not provide any information on this. Consent forms for participation were provided in all studies. Ahmed et al. [25] did not provide any information on this. The first authors declared that no conflict of interest exists. Drop-outs were mentioned in eight of the studies and can be found in Table 3.

3.3. Study outcomes

Feasibility was assessed in seven studies. Six studies could confirm the feasibility of the intervention (Ahmed et al., 2014 – *Mantram Meditation*; Diorio et al., 2015 – *Individualized Yoga*; Geyer et al., 2011 – *Bendy Kids Yoga*; Govardhan et al., 2019 – *Yoga module*; Hooke et al., 2016 – *Hatha Yoga*; Thygeson et al., 2010 – *Single yoga session* and Wurz et al., 2014 – *Community based yoga*). Only the 10-week *individualized yoga intervention* study for children and adolescents receiving outpatient cancer therapy by Stein et al. [22] did not meet the a priori defined feasibility threshold. The individual measurement criteria for feasibility can be found in Table 2 and reasons for drop-outs can be found in Table 3.

3.4. Quality of life (QoL; n = 7)

All studies used self-report and/or parent proxy-report instruments[f] (PedsQL 3.0, PedsQL 4.0 or PCQL) to assess Quality of Life. Diorio et al. [18] did not estimate the effect of individualized yoga on the QoL of hospitalized children receiving chemo because of the single armed nature of their study. The qualitative feedback from the children and parents indicated an increased QoL thanks to the intervention.

Geyer et al. [16] was able to confirm that Bendy Kids Yoga can significantly help to improve the child's perception of physical function, which is one domain of the *Pediatric Quality of Life Inventory 4.0* (PedsQL 4.0). Likewise, Orsey et al. [20] found that individualized yoga for pediatric cancer patients significantly improves the emotional, social and total scores on the PedsQL 4.0. Stein et al. [22] collected cancer-specific QoL data using the *Pediatric Quality of Life Inventory 3.0* (PedsQL 3.0), but did not conduct statistical analysis due to the small number of participants. The mindfulness-based intervention study by Van der Gucht et al. [17] was able to demonstrate an improvement in QoL using the PedsQL 4.0 in adolescents and young adult cancer survivors after 3 months. The community-based yoga intervention by Wurz et al. [24] revealed significant improvements for patient and parent reported Health Related Quality of Life using the PedsQL 4.0. Using the Pediatric Cancer Quality of Life Inventory (PCQL), however, the Mindfulness-based intervention study by Malboeuf-Hurtubise [26], however did not find significant differences between or within the

[f] Parent proxy-reported feedback form: Parents are the primary respondents while children are encouraged to share their inputs.

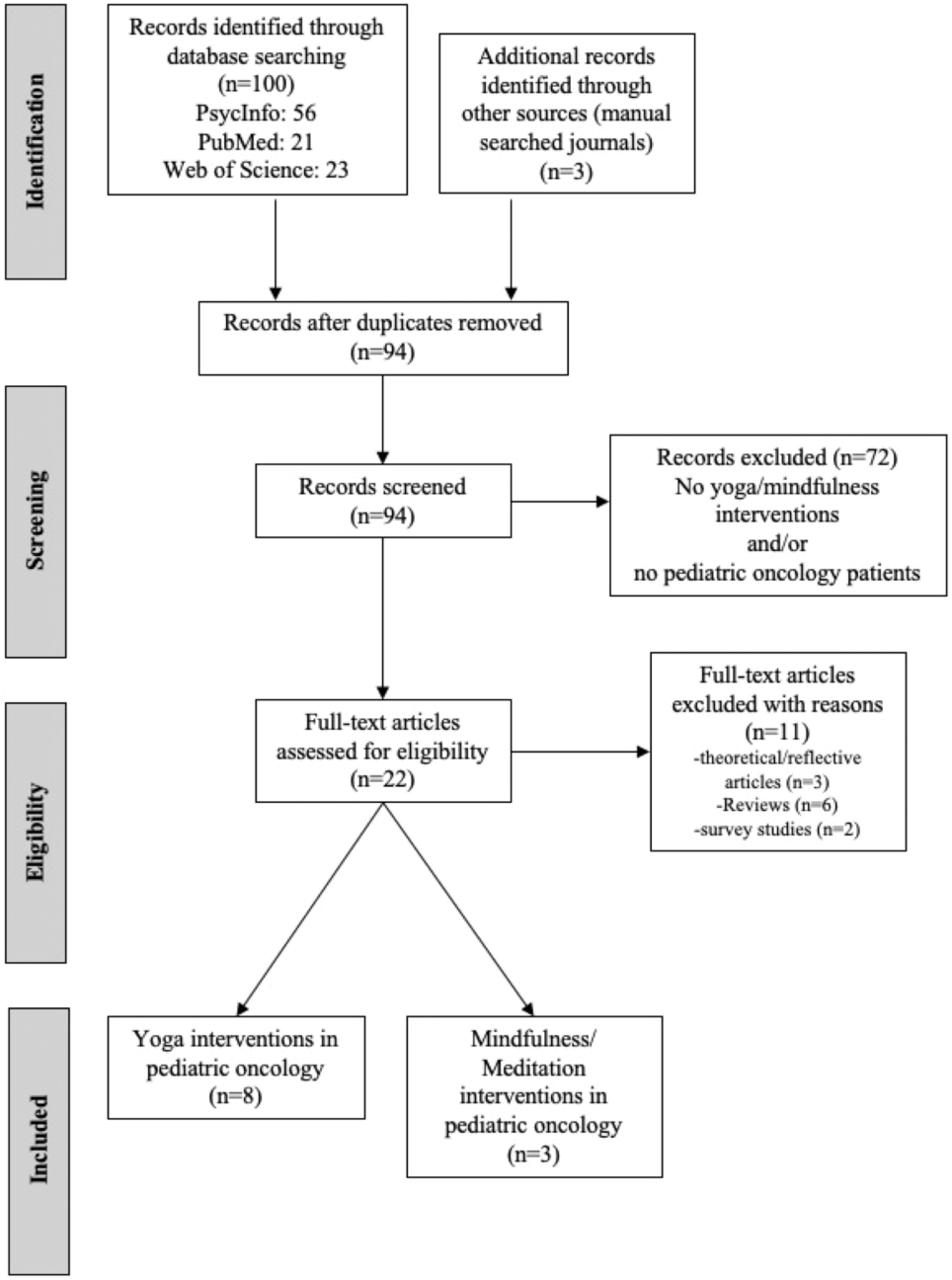

Fig. 1. Flow chart for the different phases of the systematic selection process - PRISMA 2009.

groups (intervention vs. control group) regarding quality of life.

3.5. *Fatigue (n = 5)*

Govardhan et al. [19] found that yoga can reduce fatigue symptoms significantly in pediatric brain tumor inpatients (Parent proxy-reported feedback form). Orsey et al. [20] (yoga intervention) and Diorio et al. [18] (yoga intervention) found an improvement in fatigue symptoms using Fatigue Scales in their studies, although this was not significant. Hooke et al. [23] found no significant changes in fatigue symptoms using the PEDSQL Multidimensional Fatigue Scale in their study (yoga intervention). Stein et al. [22] collected data to fatigue but did not conduct statistical analysis due to the small number of participants.

3.6. *Activity/Fitness (n = 4)*

The overall daily activity of brain tumor inpatients was found to significantly increase as reported in a Parent proxy-reported feedback form in the study by Govardhan et al. [19]. In the study of Wurz et al. [24] community based yoga for pediatric cancer outpatients helped them to improve functional mobility, hamstring flexibility and the total physical activity level significantly (measured by the Godin Leisure Time Exercise Questionnaire). Hooke et al. [23] could not find significant results in the improvement of balance in children and adolescents receiving Hatha Yoga sessions using the Bruininks-Oseretsky Test of Motor Proficiency Balance Subtext (*BOT-2)*. The score for balance remained stable post-intervention. In the yoga study by Orsey et al. [20] the physical activity levels were measured with an actical monitor to record physical activity and an activity diary. The results show improved physical activity in three children after the intervention but decreased

Table 2
Study characteristics/ intervention characteristics.

Reference	Description of the intervention	Control Group	Number of participants	n-IG[5]	n-CG[6]	Outcomes	Measurement	Main Results
1. Ahmed, Modak & Sequeira, 2014 - New York/ USA	**Mantram Meditation** (guided meditation) - during the 30 min intravenous administration of Anti-GD2 MoAb 3F8 (associated with considerable pain) - A single specific Mantram was played on an MP3 player while an experienced meditation teacher taught and led the Mantram - Duration of a Mantram meditation: 11 min	-	34	34	-	1) Feasibility 2) Efficacy (Effect of Mantram meditation on pain)	1) Feasibility was assessed by the number of patients that were able to complete a session at first or second attempt, and the total number of completed sessions relative to the total number of sessions attempted. A complete Mantram session was defined as 11 min of vocalized sound accomplished by the patient. 2) Efficacy was assessed by analyzing the peak heart rates and the number of analgesic rescues during anti-GD2 MoAb 3F8 treatment.	1) 24 patients (71%) finished meditation ($P = .44$) and of 112 started Mantram sessions 84 were finished → feasibility confirmed. 2) Analgesic rescue could be reduced (upto 14%) during treatment with anti-GD2 MoAb 3F8
2. Diorio et al., 2015- Toronto/ Canada	**Individualized Yoga** (accompanied by a family member) for hospitalized children receiving chemo. The yoga program was carried out by certified yoga instructors. Duration: 3 times a week for 3 weeks. Common structure: 1. Relaxation and breathing 2. Series of poses focused on strengthening, flexibility, and balance. 3. Period of relaxation (savasana) Yoga poses were selected from a pre-determined list. Low, moderate and high intensity regimens were available.	-	11	11	-	1. Primary outcome: Feasibility 2. Secondary outcomes: - Child Quality of Life (QoL) - Child Fatigue - Parent QoL	1. Ability to deliver at least 60% of the planned 3 times weekly sessions in at least 70% of the participants. 2. Parent-reported Pediatric Quality of Life Inventory (PedsQL) Multidimensional Fatigue Scale, Fatigue Scale-Parent, PedsQL Generic Core Scales and PedsQL Acute Cancer Module. Qualitative suggestions were also made. All instruments used a 7-day recall period (day 7, 14 and 21) except the Short Form-36 which was administered at baseline and on day 21.	1. Yoga was feasible with 10 out of 11 participants. Median number of yoga sessions: 9 (range 3–13). 2. The authors declare that "because of the single armed nature of the study, it is not possible to estimate the effect of yoga on fatigue and QoL outcomes. All median scores of the different assessment tools to fatigue and QoL are presented in the paper". Qualitative feedback from children and parents indicated physical and psychological benefits of the yoga program like increased energy levels, decreased nausea, reduced need for pain medication, reduced anxiety and agitation, better sleep and improved mood.
Reference	**Description of the intervention**	**Control Group**	**Number of participants**	**n- IG[1]**	**n-CG[2]**	**Outcomes**	**Measurement**	**Main Results**
3. Geyer, Lyons, Amazeen, Alishio & Cooks, 2011 - Seattle/ Washington/ USA	**Bendy Kids Yoga** (BKY): A low-impact exercise program, incorporating stretching, strengthening, balance, breathing technique, relaxation, and body awareness in an hour-long therapeutic yoga session. 5 Yoga sessions over 2 months, 1 yoga session per week, 1 h long. BKY instructors and assistants were physical and occupational therapists	–	6	6	–	1. Feasibility 2. Quality of Life	PedsQL 4.0 (Quality of life measured on four domains: physical-, emotional-, social- and school function)	1. Feasibility was confirmed 2. Significant score changes (0.16) at $P < .05$ in the physical domain (positive changes in walking, running, participating in play, sports and exercises…, level of aches and pains and energy level. Other domains were not significant but showed a positive trend.

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Table 2 (*continued*)

Reference	Description of the intervention	Control Group	Number of participants	n-IG[5]	n-CG[6]	Outcomes	Measurement	Main Results
1. Ahmed, Modak & Sequeira, 2014 - New York/ USA	**Mantram Meditation** (guided meditation) - during the 30 min intravenous administration of Anti-GD2 MoAb 3F8 (associated with considerable pain) - A single specific Mantram was played on an MP3 player while an experienced meditation teacher taught and led the Mantram - Duration of a Mantram meditation: 11 min	-	34	34	-	1) Feasibility 2) Efficacy (Effect of Mantram meditation on pain)	1) Feasibility was assessed by the number of patients that were able to complete a session at first or second attempt, and the total number of completed sessions relative to the total number of sessions attempted. A complete Mantram session was defined as 11 min of vocalized sound accomplished by the patient. 2) Efficacy was assessed by analyzing the peak heart rates and the number of analgesic rescues during anti-GD2 MoAb 3F8 treatment.	1) 24 patients (71%) finished meditation ($P = .44$) and of 112 started Mantram sessions 84 were finished → feasibility confirmed. 2) Analgesic rescue could be reduced (upto 14%) during treatment with anti-GD2 MoAb 3F8
2. Diorio et al., 2015- Toronto/ Canada	**Individualized Yoga** (accompanied by a family member) for hospitalized children receiving chemo. The yoga program was carried out by certified yoga instructors. Duration: 3 times a week for 3 weeks. Common structure: 1. Relaxation and breathing 2. Series of poses focused on strengthening, flexibility, and balance. 3. Period of relaxation (savasana) Yoga poses were selected from a pre-determined list. Low, moderate and high intensity regimens were available.	-	11	11	-	1. Primary outcome: Feasibility 2. Secondary outcomes: - Child Quality of Life (QoL) - Child Fatigue - Parent QoL	1. Ability to deliver at least 60% of the planned 3 times weekly sessions in at least 70% of the participants. 2. Parent-reported Pediatric Quality of Life Inventory (PedsQL) Multidimensional Fatigue Scale, Fatigue Scale-Parent, PedsQL Generic Core Scales and PedsQL Acute Cancer Module. Qualitative suggestions were also made. All instruments used a 7-day recall period (day 7, 14 and 21) except the Short Form-36 which was administered at baseline and on day 21.	1. Yoga was feasible with 10 out of 11 participants. Median number of yoga sessions: 9 (range 3–13). 2. The authors declare that "because of the single armed nature of the study, it is not possible to estimate the effect of yoga on fatigue and QoL outcomes. All median scores of the different assessment tools to fatigue and QoL are presented in the paper". Qualitative feedback from children and parents indicated physical and psychological benefits of the yoga program like increased energy levels, decreased nausea, reduced need for pain medication, reduced anxiety and agitation, better sleep and improved mood.
Reference	**Description of the intervention**	**Control Group**	**Number of participants**	**n- IG[1]**	**n-CG[2]**	**Outcomes**	**Measurement**	**Main Results**
	and assistants and received specialized training by therapeutic yoga instruction. BKY classes took place in an open space on the oncology inpatient floor in small groups up to 6 children or for children in isolation in their rooms.							
4. Govardhan et al., 2019 – Bangalore/ India	A **basic yoga module** consisting of a set of loosening, breathing, postures, relaxation, and meditation was administered for 1 h daily on weekdays, conducted after the	–	18	18	–	1) Primary outcome: Feasibility of the intervention 2) Secondary outcomes: Most common symptoms in the given population – General	1) The ability to deliver a minimum of three sessions weekly (total-5). 2) Parent proxy-reported feedback form. Parents were the primary respondents while children were	1) All participants achieved minimum required attendance. The medium number of sessions attended was 16 with a range of 12. Good acceptability of the

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Table 2 (*continued*)

Reference	Description of the intervention	Control Group	Number of participants	n-IG[5]	n-CG[6]	Outcomes	Measurement	Main Results
1. Ahmed, Modak & Sequeira, 2014 - New York/ USA	**Mantram Meditation** (guided meditation) - during the 30 min intravenous administration of Anti-GD2 MoAb 3F8 (associated with considerable pain) - A single specific Mantram was played on an MP3 player while an experienced meditation teacher taught and led the Mantram - Duration of a Mantram meditation: 11 min	-	34	34	-	1) Feasibility 2) Efficacy (Effect of Mantram meditation on pain)	1) Feasibility was assessed by the number of patients that were able to complete a session at first or second attempt, and the total number of completed sessions relative to the total number of sessions attempted. A complete Mantram session was defined as 11 min of vocalized sound accomplished by the patient. 2) Efficacy was assessed by analyzing the peak heart rates and the number of analgesic rescues during anti-GD2 MoAb 3F8 treatment.	1) 24 patients (71%) finished meditation ($P = .44$) and of 112 started Mantram sessions 84 were finished → feasibility confirmed. 2) Analgesic rescue could be reduced (upto 14%) during treatment with anti-GD2 MoAb 3F8
2. Diorio et al., 2015- Toronto/ Canada	**Individualized Yoga** (accompanied by a family member) for hospitalized children receiving chemo. The yoga program was carried out by certified yoga instructors. Duration: 3 times a week for 3 weeks. Common structure: 1. Relaxation and breathing 2. Series of poses focused on strengthening, flexibility, and balance. 3. Period of relaxation (savasana) Yoga poses were selected from a pre-determined list. Low, moderate and high intensity regimens were available.	-	11	11	-	1. Primary outcome: Feasibility 2. Secondary outcomes: - Child Quality of Life (QoL) - Child Fatigue - Parent QoL	1. Ability to deliver at least 60% of the planned 3 times weekly sessions in at least 70% of the participants. 2. Parent-reported Pediatric Quality of Life Inventory (PedsQL) Multidimensional Fatigue Scale, Fatigue Scale-Parent, PedsQL Generic Core Scales and PedsQL Acute Cancer Module. Qualitative suggestions were also made. All instruments used a 7-day recall period (day 7, 14 and 21) except the Short Form-36 which was administered at baseline and on day 21.	1. Yoga was feasible with 10 out of 11 participants. Median number of yoga sessions: 9 (range 3–13). 2. The authors declare that "because of the single armed nature of the study, it is not possible to estimate the effect of yoga on fatigue and QoL outcomes. All median scores of the different assessment tools to fatigue and QoL are presented in the paper". Qualitative feedback from children and parents indicated physical and psychological benefits of the yoga program like increased energy levels, decreased nausea, reduced need for pain medication, reduced anxiety and agitation, better sleep and improved mood.

Reference	Description of the intervention	Control Group	Number of participants	n- IG[1]	n-CG[2]	Outcomes	Measurement	Main Results
	scheduled chemo or radiotherapy session over 4 weeks within the hospital premises. The yoga sessions were provided by a trained instructor.					Health, Activity, Appreciation of pain, Nausea, Vomiting, Headache, Sleep, Distress, Loss of Appetite, Fatigue	encouraged to share their inputs. The form was administered at baseline and at the end of 4 weeks. An open-ended question to assess willingness to continue the practice at home post-discharge was also included as a parameter to assess acceptability.	program has been established. Individualized yoga is feasible for children with cancer receiving intensive chemo or radiotherapy. 2) An extremely significant difference was seen with respect to reduction in appreciation of pain ($p.$=0001), relief in headache ($p = .0005$), increase in appetite ($p = .0003$), better sleep ($p = .0003$) and reduced fatigue ($p = .007$). Increase in

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Reference	Description of the intervention	Control Group	Number of participants	n-IG[5]	n-CG[6]	Outcomes	Measurement	Main Results
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2. Diorio et al., 2015- Toronto/ Canada	**Individualized Yoga** (accompanied by a family member) for hospitalized children receiving chemo. The yoga program was carried out by certified yoga instructors. Duration: 3 times a week for 3 weeks. Common structure: 1. Relaxation and breathing 2. Series of poses focused on strengthening, flexibility, and balance. 3. Period of relaxation (savasana) Yoga poses were selected from a pre-determined list. Low, moderate and high intensity regimens were available.	-	11	11	-	1. Primary outcome: Feasibility 2. Secondary outcomes: - Child Quality of Life (QoL) - Child Fatigue - Parent QoL	1. Ability to deliver at least 60% of the planned 3 times weekly sessions in at least 70% of the participants. 2. Parent-reported Pediatric Quality of Life Inventory (PedsQL) Multidimensional Fatigue Scale, Fatigue Scale-Parent, PedsQL Generic Core Scales and PedsQL Acute Cancer Module. Qualitative suggestions were also made. All instruments used a 7-day recall period (day 7, 14 and 21) except the Short Form-36 which was administered at baseline and on day 21.	1. Yoga was feasible with 10 out of 11 participants. Median number of yoga sessions: 9 (range 3–13). 2. The authors declare that "because of the single armed nature of the study, it is not possible to estimate the effect of yoga on fatigue and QoL outcomes. All median scores of the different assessment tools to fatigue and QoL are presented in the paper". Qualitative feedback from children and parents indicated physical and psychological benefits of the yoga program like increased energy levels, decreased nausea, reduced need for pain medication, reduced anxiety and agitation, better sleep and improved mood.

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								overall daily activity was also significant ($p = .0018$).
Reference	**Description of the intervention**	**Control Group**	**Number of participants**	**n- IG[1]**	**n-CG[2]**	**Outcomes**	**Measurement**	**Main Results**
5. Hooke, Gilchrist, Foster, Langevin & Lee, 2016 – Minnesota/ USA	6-week weekly yoga intervention for paediatric cancer survivors who completed therapy in the past 2–24 month (compared with a 6-week pre-intervention wait period) Yoga class structure based on **hatha yoga**: 1. Opening seated meditation 2. Gentle stretching		13	13	–	1. feasibility 2. fatigue 3. anxiety 4. balance 5. sleep	1. Determined by how many patients met the eligibility criteria but lived more than an hour away from the institution. 2. PedsQL Multidimensional Fatigue Scale 3. Spielberger State Trait Anxiety Inventory (STAI) 4. Bruininks-Oseretsky Test of Motor Proficiency (BOT-2) Balance Subtest	-The intervention proved feasible -None of the scores for anxiety, fatigue, sleep and balance had significant changes during the wait period. -After the six-week yoga program, anxiety scores decreased significantly in children ($P = .04$).

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2. Diorio et al., 2015- Toronto/ Canada	**Individualized Yoga** (accompanied by a family member) for hospitalized children receiving chemo. The yoga program was carried out by certified yoga instructors. Duration: 3 times a week for 3 weeks. Common structure: 1. Relaxation and breathing 2. Series of poses focused on strengthening, flexibility, and balance. 3. Period of relaxation (savasana) Yoga poses were selected from a pre-determined list. Low, moderate and high intensity regimens were available.	-	11	11	-	1. Primary outcome: Feasibility 2. Secondary outcomes: - Child Quality of Life (QoL) - Child Fatigue - Parent QoL	1. Ability to deliver at least 60% of the planned 3 times weekly sessions in at least 70% of the participants. 2. Parent-reported Pediatric Quality of Life Inventory (PedsQL) Multidimensional Fatigue Scale, Fatigue Scale-Parent, PedsQL Generic Core Scales and PedsQL Acute Cancer Module. Qualitative suggestions were also made. All instruments used a 7-day recall period (day 7, 14 and 21) except the Short Form-36 which was administered at baseline and on day 21.	1. Yoga was feasible with 10 out of 11 participants. Median number of yoga sessions: 9 (range 3–13). 2. The authors declare that "because of the single armed nature of the study, it is not possible to estimate the effect of yoga on fatigue and QoL outcomes. All median scores of the different assessment tools to fatigue and QoL are presented in the paper". Qualitative feedback from children and parents indicated physical and psychological benefits of the yoga program like increased energy levels, decreased nausea, reduced need for pain medication, reduced anxiety and agitation, better sleep and improved mood.

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	3. Warm up poses, standing poses, balancing poses, seated and supine cool down stretches, and final resting pose. Duration: 45 min Children were allowed to bring friends, siblings or parents to the class.						5. The Adolescent Sleep-Wake Scale (ASWS) Measurement times: 3 times 1. Week one of the study (start of the pre-intervention wait period); 2. Week 6 (after wait period) and immediately before first yoga class; 3. Week 11 after the sixth yoga session was completed.	Adolescent anxiety scores showed a decreasing trend. -Scores for fatigue, sleep and balance remained stable post-intervention
6. Malboeuf-Hurtubise et al., 2016 – Montreal/ Canada	**Mindfulness-based intervention** (MBI) for adolescents with cancer. Two trained therapists	Yes (no treatment)	13	7	6	1. Quality of Life (QoL) 2. Sleep 3. Mood 4. Mindfulness	1. Paediatric Cancer Quality of life inventory 2. Pittsburgh Sleep Quality Index 3. Beck Youth Inventory	No significant differences between or within groups were found pre to post assessment and at

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2. Diorio et al., 2015- Toronto/ Canada	**Individualized Yoga** (accompanied by a family member) for hospitalized children receiving chemo. The yoga program was carried out by certified yoga instructors. Duration: 3 times a week for 3 weeks. Common structure: 1. Relaxation and breathing 2. Series of poses focused on strengthening, flexibility, and balance. 3. Period of relaxation (savasana) Yoga poses were selected from a pre-determined list. Low, moderate and high intensity regimens were available.	-	11	11	-	1. Primary outcome: Feasibility 2. Secondary outcomes: - Child Quality of Life (QoL) - Child Fatigue - Parent QoL	1. Ability to deliver at least 60% of the planned 3 times weekly sessions in at least 70% of the participants. 2. Parent-reported Pediatric Quality of Life Inventory (PedsQL) Multidimensional Fatigue Scale, Fatigue Scale-Parent, PedsQL Generic Core Scales and PedsQL Acute Cancer Module. Qualitative suggestions were also made. All instruments used a 7-day recall period (day 7, 14 and 21) except the Short Form-36 which was administered at baseline and on day 21.	1. Yoga was feasible with 10 out of 11 participants. Median number of yoga sessions: 9 (range 3–13). 2. The authors declare that "because of the single armed nature of the study, it is not possible to estimate the effect of yoga on fatigue and QoL outcomes. All median scores of the different assessment tools to fatigue and QoL are presented in the paper". Qualitative feedback from children and parents indicated physical and psychological benefits of the yoga program like increased energy levels, decreased nausea, reduced need for pain medication, reduced anxiety and agitation, better sleep and improved mood.

Reference	Description of the intervention	Control Group	Number of participants	n- IG[1]	n-CG[2]	Outcomes	Measurement	Main Results
	led the intervention. MBI group met for 8 weeks with a 90-min session per week. Homework was assigned every week, and daily home practice was strongly encouraged. Guided meditations were recorded and a copy was given to each participant for home use. Mindfulness practices during sessions: Mindful eating, Body scan meditation, Breathing meditation,					Feasibility and Acceptability	& Positive and Negative Affect Schedule – Child 4. Children and Adolescent Mindfulness Measure Measurement times: Baseline, Post intervention (8 weeks), Follow-up (6 month)	follow-up. Participants of the MBI-group reported having liked the opportunity to speak openly about their emotions in a peer group setting. All indicated discovering mindfulness as a helpful tool for identifying emotions and managing stress at school.

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	Acceptance on thoughts, emotions and physical sensations, heartfulness meditation, mountain meditation, walking meditation etc.							
Reference	**Description of the intervention**	**Control Group**	**Number of participants**	**n- IG[1]**	**n-CG[2]**	**Outcomes**	**Measurement**	**Main Results**
7. Orsey et al., 2017 – Washington/ USA	**Individualized yoga** for paediatric cancer patients in active treatment and for their families. The yoga intervention was led by one of 2 certified yoga instructors. Possible yoga selection:	–	20	10	–	1. Fatigue 2. Quality of Life (QoL) 3. Physical activity 4. Satisfaction with the program Secondary outcomes: Caregivers well-	1. The Fatigue Scale (Fatigue Scale - Child, Fatigue Scale-Adolescent, Fatigue Scale-Parent) 2. Pediatric Quality if Life 4.0 (PedsQL 4.0) + PedsQL 3.0 3. Actigraphy (Actical monitor to record	1. Not significant 2. Significant increases in emotional ($P = .03$), social function ($P = .03$), and total scores ($P = .006$) on the PedsQL 4.0. The parents' version of the PedsQL 4.0 revealed

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	a) bedside yoga on the inpatient floor b) classroom yoga in a family or conference room c) chair yoga in a family or conference room. Structure of the yoga class: 1) 10 min of breathing 2) 25 min of yoga asana (postures) 3) 15 min of relaxation At least 4 yoga sessions (60 min) over an 8-week enrollment period.					being (QoL and burden)	physical activity) + Activity data (activity diary) 4. Yoga satisfaction Survey Secondary outcomes (Parent Outcomes and caregiver Burden): - Health-Related Quality of Life (HRQOL)-Short Form (SF-12) - Caregiver Burden Interview survey - Yoga Satisfaction Survey	no significant changes. 3. Data were available at the start and end of the study for 7 participants, 3 of whom increased activity whereas 4 decreased activity. The paired *t*-test was not significant ($P = .93$). Secondary Outcomes: Parent HRQOL and caregiver burden: Parents' Mental Health Composite Scale (MCS) on the SF-12 Health Survey

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								significantly improved ($P < .05$). No differences were noted for the Physical Health Composite or caregiver burden. Satisfaction with intervention: Patients and Parents found the yoga helpful and were quite satisfied.
8. Stein et al., 2019 – Toronto/ Canada	10-week, weekly **individualized yoga** intervention (45 min per session) for children and adolescents receiving outpatient cancer	–	10	10	–	1) Primary Outcome: Feasibility 2) Secondary Outcomes: anxiety, depression, anger and fatigue,	1) Feasibility defined as enrollment of at least 10 patients over 1 year and completion of at least 60% (n = 6) of planned yoga sessions in at least 80% of participants.	1) Only six participants achieved at least 60% of planned yoga sessions and thus, the study did not meet the a priori defined

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	therapy. Weeks 1, 5, and 10 were in-hospital while the remaining sessions were delivered remotely using Skype. Twice weekly, homework (relaxation and breathing exercises) was assigned. All yoga instructors were certified yoga teachers Session structure: 1) breathing exercises 2) warm-up exercises 3) standing, seated and supine postures 4) final relaxation					Cancer-specific quality of life	2) Patient-Reported Outcomes Measurement Information System (PROMIS) short forms. - Fatigue was also measured using the self-report Pediatric Quality of Life (PedsQL) Multidimensional Fatigue Scale (MFS) - Cancer specific quality of life and bothersome symptoms were measured using the self-report PedsQL 3.0 Acute Cancer Module and Symptom Screening in Pediatrics Tool (SSPedi) Measurement Times:	feasibility threshold. Among all participants, only one homework session was performed. 2) Due to the small number of participants no statistical analysis was conducted.

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Reference	Description of the intervention	Control Group	Number of participants	n-IG[5]	n-CG[6]	Outcomes	Measurement	Main Results
1. Ahmed, Modak & Sequeira, 2014 - New York/ USA	**Mantram Meditation** (guided meditation) - during the 30 min intravenous administration of Anti-GD2 MoAb 3F8 (associated with considerable pain) - A single specific Mantram was played on an MP3 player while an experienced meditation teacher taught and led the Mantram - Duration of a Mantram meditation: 11 min	-	34	34	-	1) Feasibility 2) Efficacy (Effect of Mantram meditation on pain)	1) Feasibility was assessed by the number of patients that were able to complete a session at first or second attempt, and the total number of completed sessions relative to the total number of sessions attempted. A complete Mantram session was defined as 11 min of vocalized sound accomplished by the patient. 2) Efficacy was assessed by analyzing the peak heart rates and the number of analgesic rescues during anti-GD2 MoAb 3F8 treatment.	1) 24 patients (71%) finished meditation ($P = .44$) and of 112 started Mantram sessions 84 were finished → feasibility confirmed. 2) Analgesic rescue could be reduced (upto 14%) during treatment with anti-GD2 MoAb 3F8
2. Diorio et al., 2015- Toronto/ Canada	**Individualized Yoga** (accompanied by a family member) for hospitalized children receiving chemo. The yoga program was carried out by certified yoga instructors. Duration: 3 times a week for 3 weeks. Common structure: 1. Relaxation and breathing 2. Series of poses focused on strengthening, flexibility, and balance. 3. Period of relaxation (savasana) Yoga poses were selected from a pre-determined list. Low, moderate and high intensity regimens were available.	-	11	11	-	1. Primary outcome: Feasibility 2. Secondary outcomes: - Child Quality of Life (QoL) - Child Fatigue - Parent QoL	1. Ability to deliver at least 60% of the planned 3 times weekly sessions in at least 70% of the participants. 2. Parent-reported Pediatric Quality of Life Inventory (PedsQL) Multidimensional Fatigue Scale, Fatigue Scale-Parent, PedsQL Generic Core Scales and PedsQL Acute Cancer Module. Qualitative suggestions were also made. All instruments used a 7-day recall period (day 7, 14 and 21) except the Short Form-36 which was administered at baseline and on day 21.	1. Yoga was feasible with 10 out of 11 participants. Median number of yoga sessions: 9 (range 3–13). 2. The authors declare that "because of the single armed nature of the study, it is not possible to estimate the effect of yoga on fatigue and QoL outcomes. All median scores of the different assessment tools to fatigue and QoL are presented in the paper". Qualitative feedback from children and parents indicated physical and psychological benefits of the yoga program like increased energy levels, decreased nausea, reduced need for pain medication, reduced anxiety and agitation, better sleep and improved mood.

Reference	Description of the intervention	Control Group	Number of participants	n- IG[1]	n-CG[2]	Outcomes	Measurement	Main Results
							Baseline, 5 and 10 weeks after enrollment	
Reference	**Description of the intervention**	**Control Group**	**Number of participants**	**n- IG[1]**	**n-CG[2]**	**Outcomes**	**Measurement**	**Main Results**
9. Thygeson, Hooke, Clapsaddle, Robbins & Moquist, 2010 – Minnesota/ USA	**Single yoga session** on an inpatient hematology/oncology unit for children with cancer and their parents. The yoga class, held in the inpatient unit playroom, was administered by a registered yoga teacher. Duration: 45 min Session structure: Opening seated	–	11 children, 5 adoles-cents and 33 parents	11 children, 5 adoles-cents and 33 parents	–	1) Anxiety and general sense of well-being pre- and postclass 2) Feasibility of the yoga intervention	1) Spielberger State Anxiety Scale 2) Qualitative data were collected using an open-ended survey question administered after the class.	Children had normal anxiety scores pre-class that did not change. Adolescents experienced a significant decrease in anxiety with an improved sense of well-being. Parents also experienced a significant decrease in anxiety and an increased sense of

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Table 2 (*continued*)

Reference	Description of the intervention	Control Group	Number of participants	n-IG[5]	n-CG[6]	Outcomes	Measurement	Main Results
1. Ahmed, Modak & Sequeira, 2014 - New York/ USA	**Mantram Meditation** (guided meditation) - during the 30 min intravenous administration of Anti-GD2 MoAb 3F8 (associated with considerable pain) - A single specific Mantram was played on an MP3 player while an experienced meditation teacher taught and led the Mantram - Duration of a Mantram meditation: 11 min	-	34	34	-	1) Feasibility 2) Efficacy (Effect of Mantram meditation on pain)	1) Feasibility was assessed by the number of patients that were able to complete a session at first or second attempt, and the total number of completed sessions relative to the total number of sessions attempted. A complete Mantram session was defined as 11 min of vocalized sound accomplished by the patient. 2) Efficacy was assessed by analyzing the peak heart rates and the number of analgesic rescues during anti-GD2 MoAb 3F8 treatment.	1) 24 patients (71%) finished meditation ($P = .44$) and of 112 started Mantram sessions 84 were finished → feasibility confirmed. 2) Analgesic rescue could be reduced (upto 14%) during treatment with anti-GD2 MoAb 3F8
2. Diorio et al., 2015- Toronto/ Canada	**Individualized Yoga** (accompanied by a family member) for hospitalized children receiving chemo. The yoga program was carried out by certified yoga instructors. Duration: 3 times a week for 3 weeks. Common structure: 1. Relaxation and breathing 2. Series of poses focused on strengthening, flexibility, and balance. 3. Period of relaxation (savasana) Yoga poses were selected from a pre-determined list. Low, moderate and high intensity regimens were available.	-	11	11	-	1. Primary outcome: Feasibility 2. Secondary outcomes: - Child Quality of Life (QoL) - Child Fatigue - Parent QoL	1. Ability to deliver at least 60% of the planned 3 times weekly sessions in at least 70% of the participants. 2. Parent-reported Pediatric Quality of Life Inventory (PedsQL) Multidimensional Fatigue Scale, Fatigue Scale-Parent, PedsQL Generic Core Scales and PedsQL Acute Cancer Module. Qualitative suggestions were also made. All instruments used a 7-day recall period (day 7, 14 and 21) except the Short Form-36 which was administered at baseline and on day 21.	1. Yoga was feasible with 10 out of 11 participants. Median number of yoga sessions: 9 (range 3–13). 2. The authors declare that "because of the single armed nature of the study, it is not possible to estimate the effect of yoga on fatigue and QoL outcomes. All median scores of the different assessment tools to fatigue and QoL are presented in the paper". Qualitative feedback from children and parents indicated physical and psychological benefits of the yoga program like increased energy levels, decreased nausea, reduced need for pain medication, reduced anxiety and agitation, better sleep and improved mood.
Reference	**Description of the intervention**	**Control Group**	**Number of participants**	**n- IG[1]**	**n-CG[2]**	**Outcomes**	**Measurement**	**Main Results**
	meditation, Warm-up and centering poses, standing poses, balance poses, cool-down/ spinal twists, and final resting pose.							well-being ($P = .04$). All cohorts gave positive feedback about the experience.
10. Van der Gucht et al., 2017 – Leuven/ Belgium	**Mindfulness-based intervention** (MBI) to alleviate emotional distress and improve quality of life (QoL) in adolescents and young adults cancer (AYAC) survivors. The MBI program adhered to Mindfulness-Based Stress Reduction (MBSR) and	–	16	16	–	1) Primary outcome variables: -emotional distress -QoL 2) Secondary outcome variables: -cognitive vulnerability factors -mindfulness skills	1) Primary outcomes: QoL: Pediatric Quality of Life Inventory (PedsQL 4.0); Emotional distress: Depression Anxiety Scales (DASS-21) 2) Secondary outcomes: -Leiden Index of Depression Sensitivity (LEIDS-R) -The dampening subscale of the Responses to	1) Significant reduction in emotional distress ($p < .001$) and improvement in QoL ($p = .002$) at 3 months of follow-up 2) Significant reduction in negative attitudes toward self ($p < .001$) (i.e., a cognitive vulnerability factor)

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Table 2 (*continued*)

Reference	Description of the intervention	Control Group	Number of participants	n-IG[5]	n-CG[6]	Outcomes	Measurement	Main Results
1. Ahmed, Modak & Sequeira, 2014 - New York/ USA	**Mantram Meditation** (guided meditation) - during the 30 min intravenous administration of Anti-GD2 MoAb 3F8 (associated with considerable pain) - A single specific Mantram was played on an MP3 player while an experienced meditation teacher taught and led the Mantram - Duration of a Mantram meditation: 11 min	-	34	34	-	1) Feasibility 2) Efficacy (Effect of Mantram meditation on pain)	1) Feasibility was assessed by the number of patients that were able to complete a session at first or second attempt, and the total number of completed sessions relative to the total number of sessions attempted. A complete Mantram session was defined as 11 min of vocalized sound accomplished by the patient. 2) Efficacy was assessed by analyzing the peak heart rates and the number of analgesic rescues during anti-GD2 MoAb 3F8 treatment.	1) 24 patients (71%) finished meditation ($P = .44$) and of 112 started Mantram sessions 84 were finished → feasibility confirmed. 2) Analgesic rescue could be reduced (upto 14%) during treatment with anti-GD2 MoAb 3F8
2. Diorio et al., 2015- Toronto/ Canada	**Individualized Yoga** (accompanied by a family member) for hospitalized children receiving chemo. The yoga program was carried out by certified yoga instructors. Duration: 3 times a week for 3 weeks. Common structure: 1. Relaxation and breathing 2. Series of poses focused on strengthening, flexibility, and balance. 3. Period of relaxation (savasana) Yoga poses were selected from a pre-determined list. Low, moderate and high intensity regimens were available.	-	11	11	-	1. Primary outcome: Feasibility 2. Secondary outcomes: - Child Quality of Life (QoL) - Child Fatigue - Parent QoL	1. Ability to deliver at least 60% of the planned 3 times weekly sessions in at least 70% of the participants. 2. Parent-reported Pediatric Quality of Life Inventory (PedsQL) Multidimensional Fatigue Scale, Fatigue Scale-Parent, PedsQL Generic Core Scales and PedsQL Acute Cancer Module. Qualitative suggestions were also made. All instruments used a 7-day recall period (day 7, 14 and 21) except the Short Form-36 which was administered at baseline and on day 21.	1. Yoga was feasible with 10 out of 11 participants. Median number of yoga sessions: 9 (range 3–13). 2. The authors declare that "because of the single armed nature of the study, it is not possible to estimate the effect of yoga on fatigue and QoL outcomes. All median scores of the different assessment tools to fatigue and QoL are presented in the paper". Qualitative feedback from children and parents indicated physical and psychological benefits of the yoga program like increased energy levels, decreased nausea, reduced need for pain medication, reduced anxiety and agitation, better sleep and improved mood.

Reference	Description of the intervention	Control Group	Number of participants	n- IG[1]	n-CG[2]	Outcomes	Measurement	Main Results
	Mindfulness-Based Cognitive Therapy (MBCT) manuals. The program consists of eight 90-minute sessions that were held once a week for 8 consecutive weeks. Guided experiential mindfulness exercises were taught combined with psycho-education. Sessions took place outside the hospital in a mental health center or in a monastery. The program was provided by a clinical psychologist.						Positive Affect (RPA) questionnaire -Attitudes Toward Self Revised (ATS-R) -Fear of Cancer Recurrence Inventory severity subscale (FCRI) -The Children's Acceptance and Mindfulness Measure (CAMM) -Level of engagement was measured with homework	and a significant improvement in mindfulness skills ($p < .001$).

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Table 2 (*continued*)

Reference	Description of the intervention	Control Group	Number of participants	n-IG[5]	n-CG[6]	Outcomes	Measurement	Main Results
1. Ahmed, Modak & Sequeira, 2014 - New York/ USA	**Mantram Meditation** (guided meditation) - during the 30 min intravenous administration of Anti-GD2 MoAb 3F8 (associated with considerable pain) - A single specific Mantram was played on an MP3 player while an experienced meditation teacher taught and led the Mantram - Duration of a Mantram meditation: 11 min	-	34	34	-	1) Feasibility 2) Efficacy (Effect of Mantram meditation on pain)	1) Feasibility was assessed by the number of patients that were able to complete a session at first or second attempt, and the total number of completed sessions relative to the total number of sessions attempted. A complete Mantram session was defined as 11 min of vocalized sound accomplished by the patient. 2) Efficacy was assessed by analyzing the peak heart rates and the number of analgesic rescues during anti-GD2 MoAb 3F8 treatment.	1) 24 patients (71%) finished meditation ($P = .44$) and of 112 started Mantram sessions 84 were finished → feasibility confirmed. 2) Analgesic rescue could be reduced (upto 14%) during treatment with anti-GD2 MoAb 3F8
2. Diorio et al., 2015- Toronto/ Canada	**Individualized Yoga** (accompanied by a family member) for hospitalized children receiving chemo. The yoga program was carried out by certified yoga instructors. Duration: 3 times a week for 3 weeks. Common structure: 1. Relaxation and breathing 2. Series of poses focused on strengthening, flexibility, and balance. 3. Period of relaxation (savasana) Yoga poses were selected from a pre-determined list. Low, moderate and high intensity regimens were available.	-	11	11	-	1. Primary outcome: Feasibility 2. Secondary outcomes: - Child Quality of Life (QoL) - Child Fatigue - Parent QoL	1. Ability to deliver at least 60% of the planned 3 times weekly sessions in at least 70% of the participants. 2. Parent-reported Pediatric Quality of Life Inventory (PedsQL) Multidimensional Fatigue Scale, Fatigue Scale-Parent, PedsQL Generic Core Scales and PedsQL Acute Cancer Module. Qualitative suggestions were also made. All instruments used a 7-day recall period (day 7, 14 and 21) except the Short Form-36 which was administered at baseline and on day 21.	1. Yoga was feasible with 10 out of 11 participants. Median number of yoga sessions: 9 (range 3–13). 2. The authors declare that "because of the single armed nature of the study, it is not possible to estimate the effect of yoga on fatigue and QoL outcomes. All median scores of the different assessment tools to fatigue and QoL are presented in the paper". Qualitative feedback from children and parents indicated physical and psychological benefits of the yoga program like increased energy levels, decreased nausea, reduced need for pain medication, reduced anxiety and agitation, better sleep and improved mood.

Reference	Description of the intervention	Control Group	Number of participants	n- IG[1]	n-CG[2]	Outcomes	Measurement	Main Results

Reference	Description of the intervention	Control Group	Number of participants	n-IG[1]	n-CG[2]	Outcomes	Measurement	Main Results
11. Wurz, Chamorro-Vina, Guilcher, Schulte & Culos-Reed, 2014 – Calgary/ Canada	12-week **community based yoga intervention** consisting of supervised yoga sessions 2 times/week at a location in the local community. Session structure: Warm-up, supine/ seated/kneeling poses, standing poses, group poses, group activity, supine/seated/ kneeling/prone poses, cool-down, and a final resting pose.	–	8	8	–	1) Feasibility of the intervention 2) Health Related Quality of Life (HRQL) 3) Select physical fitness outcomes (functional mobility, flexibility and Range of Motion (ROM) and Physical Activity Level (PAL)	1) Measured by recruitment, attendance, retention and adverse events. 2) HRQL: Patient and parent-proxy reports on the Pediatric Quality of Life (PedsQL) 4.0 General Module. 3) Physical Fitness: Battery of assessments. -Functional Mobility: "Timed up and Go" (TUG)– 3 m. -Flexibility of the hamstrings: Back-Saver Sit and Reach-Test.	Rates of recruitment, retention, attendance and adverse events indicated the program was feasible. Significant improvements for patient ($P = .02$) and parent reported HRQL ($P = .03$), functional mobility ($P = .01$), hamstring flexibility (left $P = .01$) and right ($P = .02$), and total PAL ($P = .02$) pre to post intervention.

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Table 2 (*continued*)

Reference	Description of the intervention	Control Group	Number of participants	n-IG[5]	n-CG[6]	Outcomes	Measurement	Main Results
1. Ahmed, Modak & Sequeira, 2014 - New York/ USA	**Mantram Meditation** (guided meditation) - during the 30 min intravenous administration of Anti-GD2 MoAb 3F8 (associated with considerable pain) - A single specific Mantram was played on an MP3 player while an experienced meditation teacher taught and led the Mantram - Duration of a Mantram meditation: 11 min	-	34	34	-	1) Feasibility 2) Efficacy (Effect of Mantram meditation on pain)	1) Feasibility was assessed by the number of patients that were able to complete a session at first or second attempt, and the total number of completed sessions relative to the total number of sessions attempted. A complete Mantram session was defined as 11 min of vocalized sound accomplished by the patient. 2) Efficacy was assessed by analyzing the peak heart rates and the number of analgesic rescues during anti-GD2 MoAb 3F8 treatment.	1) 24 patients (71%) finished meditation ($P = .44$) and of 112 started Mantram sessions 84 were finished → feasibility confirmed. 2) Analgesic rescue could be reduced (upto 14%) during treatment with anti-GD2 MoAb 3F8
2. Diorio et al., 2015- Toronto/ Canada	**Individualized Yoga** (accompanied by a family member) for hospitalized children receiving chemo. The yoga program was carried out by certified yoga instructors. Duration: 3 times a week for 3 weeks. Common structure: 1. Relaxation and breathing 2. Series of poses focused on strengthening, flexibility, and balance. 3. Period of relaxation (savasana) Yoga poses were selected from a pre-determined list. Low, moderate and high intensity regimens were available.	-	11	11	-	1. Primary outcome: Feasibility 2. Secondary outcomes: - Child Quality of Life (QoL) - Child Fatigue - Parent QoL	1. Ability to deliver at least 60% of the planned 3 times weekly sessions in at least 70% of the participants. 2. Parent-reported Pediatric Quality of Life Inventory (PedsQL) Multidimensional Fatigue Scale, Fatigue Scale-Parent, PedsQL Generic Core Scales and PedsQL Acute Cancer Module. Qualitative suggestions were also made. All instruments used a 7-day recall period (day 7, 14 and 21) except the Short Form-36 which was administered at baseline and on day 21.	1. Yoga was feasible with 10 out of 11 participants. Median number of yoga sessions: 9 (range 3–13). 2. The authors declare that "because of the single armed nature of the study, it is not possible to estimate the effect of yoga on fatigue and QoL outcomes. All median scores of the different assessment tools to fatigue and QoL are presented in the paper". Qualitative feedback from children and parents indicated physical and psychological benefits of the yoga program like increased energy levels, decreased nausea, reduced need for pain medication, reduced anxiety and agitation, better sleep and improved mood.
Reference	**Description of the intervention**	**Control Group**	**Number of participants**	**n- IG[1]**	**n-CG[2]**	**Outcomes**	**Measurement**	**Main Results**
	Instructors were required to hold yoga certifications.						Range of Motion of the ankle: Goniometry, measuring both passive and active dorsiflexion (DF)-ROM - Physical Activity Levels were assessed subjectively using the Godin leisure score index (LSI) of the Godin Leisure Time Exercise Questionnaire (GLTEQ) Measurement times: Baseline and post-intervention	

Abbreviations:

[5] n -IG: Number of participants in intervention group.

[6] n -CG: Number of participants in control group.

Table 3
Quality aspects: Study design and drop-out rates with reasons for each study.

Reference	Study Design	Total n[7]	Drop-outs				
			n	n-IG[8]	n-CG[9]	Recorded?	Reasons
1. Ahmed, Modak & Sequeira (2014)	Retrospective study, not randomized, no control group	34	10	10	–	yes	11 min of meditation could not be completed. Not explained in detail.
2. Diorio et al. (2015)	Single armed pilot study	11	1	1	–	yes	Exercises were not "fast paced" enough. (After third yoga session, 7 years old)
3. Geyer, Lyons, Amazeen, Alishio & Cooks (2011)	One group, within subject, repeated measure design (exploratory study)	6	–	–	–	–	–
4. Govardhan et al. (2019)	Single armed pre-post intervention pilot study	18	–	–	–	–	–
5. Hooke, Gilchrist, Foster, Langevin & Lee (2016)	One group, within subject, repeated measure design	13	5	2	3	yes	- Relapse (n = 2) - Unknown reasons (n = 3; drop out during waiting period)
6. Malboeuf-Hurtubise et al. (2016)	Prospective quasi-experimental pretest- posttest design with two groups. Randomization was planned but slow recruitment and low numbers of participants made randomization impossible.	13	–	–	–	–	–
7. Orsey et al. (2017)	Single-armed-clinical trial	20	12	Not reported	–	yes	- Withdrawal due to treatment (n = 6) - "Study Window Lapse" (n = 6)
8. Stein et al. (2019)	Single armed pilot study	10	2	2	–	yes	- Not interested (n = 1) - Too sick (n = 1)
9. Thygeson, Hooke, Clapsaddle, Robbins & Moquist (2010)	Mixed-methods, within-subject, repeated measures design (1 children cohort, 1 adolescents cohort, 1 parents cohort)	11 children, 5 adolescents and 33 parents	1 child + 1 parent	–	–	yes	Child because of dizziness, Parent because of emotional distress due to child's diagnosis
10. Van der Gucht et al. (2017)	Two-baseline (8 and 1 week before the intervention), post- (1 week after the intervention) and 3 months follow-up within-subjects design	16	2	2	–	yes	Illness
11. Wurz, Chamorro-Vina, Guilcher, Schulte & Culos-Reed (2014)	Single armed pre-post intervention pilot study	8	3	3	–	Yes	- Didn't like yoga practice (n = 1) - Returned to school (n = 1) -Too busy (n = 1)

[7] Total n: Total number of participants.
[8] n-IG: number of participants in Intervention group.
[9] n-CG: number of participants in control group.

physical activity in four children. The paired *t*-test was not significant.

3.7. Sleep (n = 4)

Yoga was shown to improve sleep significantly (Parent proxy-reported feedback form) as was shown in Govardhan et al. [19]. In the Hatha yoga study by Hooke et al. [23] the score for sleep remained stable post intervention (Adolescent Sleep-Wake Scale; ASWS). The mindfulness-intervention by Malboeuf-Hurtubise et al. [26] did not find significant differences between or within groups pre to post assessment and at follow up when it comes to sleep (Pittsburgh Sleep Quality Index). In the study of Diorio et al. [18] qualitative feedback from children and parents indicated better sleep due to the yoga intervention.

3.8. Anxiety (n = 3)

Using the Spielberger State Trait Anxiety Inventory (STAI) the yoga study by Hooke et al. [23] demonstrated that anxiety scores decreased significantly in children after the six-week-intervention. Adolescent anxiety scores showed a decreasing trend. Thygeson et al. [21] confirmed that a single yoga session on an inpatient hematology/oncology unit can decrease anxiety scores of adolescent patients and parents significantly. Children had normal anxiety scores before the yoga session that did not change (Spielberger State Anxiety Scale). Stein et al. [22] collected data to anxiety but did not conduct statistical analysis due to the small number of participants.

3.9. Pain (n = 2)

In the study by Ahmed et al. [25] mantram meditation helped to reduce the analgesic rescue up to 14% during treatment with anti-GD2 MoAb 3F8. Govardhan et al. [19] also found that yoga can help to reduce the appreciation of pain and a relief in headache significantly (Parent proxy-reported feedback form).

3.10. Mindfulness (n = 2)

The study by Malboeuf-Hurtubise et al. [26] did not find significant differences between or within groups pre to post assessment and at follow up when it comes to mindfulness (Children and Adolescent Mindfulness Measure). A qualitative report of the participants in the mindfulness-group indicated that discovering mindfulness was a helpful

tool to identify emotions and manage stress at school. Van der Gucht et al. [17] exhibited that a mindfulness-based intervention for adolescents and young adult cancer survivors can reduce negative attitudes toward self and improve mindfulness skills significantly (The Children's Acceptance and Mindfulness Measure; CAMM).

3.11. Emotional distress (n = 1)

By using the Depression Anxiety Scales (DASS-21) Van der Gucht et al. [17] ascertained that a mindfulness-based intervention can reduce emotional distress significantly in adolescent and young adult cancer survivors.

3.12. Appetite (n = 1)

Findings from Govardhan et al. [19] upheld that next to other improvements, yoga can increase appetite significantly for pediatric brain-tumor inpatients (Parent proxy-reported feedback form).

4. Discussion

The review by Danhauer et al. (2017) focused on studies providing yoga therapy *during* cancer treatment. At the time of their research, the authors identified four studies that examined yoga therapy during cancer treatment for pediatric patients [16,18,21,24]. Our update identified three additional studies in this context [19,20,22] that contribute to a wider evidence base of yoga/MBM use in pediatric oncology. In addition, we were able to add one study that dealt with yoga therapy for pediatrics specifically *after* cancer treatment [23]. Given the extensive overlap in philosophy and practice, we decided to also include studies that used a mindfulness or meditation intervention. With this widened scope, we were able to include three more studies and review a total of eleven studies on yoga, meditation, and mindfulness in a current and former pediatric oncology population.

The reviewed studies were able to determine that yoga and mindfulness-based interventions for children and adolescents with oncological illness are feasible in inpatient, outpatient, or community settings and are well-received. The results of the studies suggest that yoga and mindfulness may help to improve the quality of life, reduce fatigue, improve activity and fitness levels, improve sleep quality, increase appetite and decrease anxiety in various stages of the illness and treatment. In addition, there are some indications, that mantram meditation can reduce pain and the need for analgesic rescue during anti-GD2 MoAb 3F8 treatment [25]. Mindfulness-interventions may support pediatric patients and former patients in gaining access to the own emotions and to manage stress. In addition, a negative attitude toward self and mindfulness skills in general may be improved with these interventions.

4.1. Challenges in and conclusion of the review of literature

Given the overall heterogeneous nature of the studies and design, comparisons between them proved challenging. On the one hand, the patient populations differed in terms of diseases and conventional therapies. The interventions examined also covered a wide range, both in terms of intervention time period, frequency and duration of the individual treatments, as well as structure, course and location of the individual practice sessions. In the study by Hooke et al. [23], for instance, patients were instructed to repeat the contents of the yoga classes regularly at home and received a specially made DVD with the corresponding exercises for support. Some participants received individual treatment while in some studies treatment was undertaken in groups or were encouraged to bring a treatment companion (parents, siblings, friends). All these factors may influence the treatment and thus also the treatment effect.

The greatest limitation to this review is that only eight current studies specific to implementing yoga in pediatric oncology could be identified. Moreover, only three studies could be evaluated that dealt with mindfulness in pediatric oncology. Despite the fact that papers examined in this review were intervention studies, none were randomized and only one of the studies had a control group arm. Randomization appears to be a particular challenge when it comes to MBM interventions in pediatric oncology. Furthermore, all studies have very small case numbers, and therefore limited statistical power, which was reflected in the authors' own conclusions. In sum, the available studies have a reduced internal validity due to lack of control groups and randomization, small sample sizes or participant numbers, and heterogeneous study designs.

Regarding the drop-outs, two major reasons were apparent. On the one hand, disease related reasons led to the drop-out, such as relapse, being too ill or dizziness. On the other hand, drop-outs were seen due to the age-specific target group of children and adolescents. While most were found to enjoy the yoga and mindfulness interventions, some children reacted with disinterest or boredom to the exercises resulting in drop-out. Whereas reasons for drop-out cannot be completely avoided, future study designs should take high drop-out rates into account that can lead to distortions.

In summary, efficacy of yoga and mindfulness-based interventions in pediatric oncological patients and former patients cannot be concluded based on the current body of evidence and available studies shown in this review of literature. This seems not only to be due to the small number of studies and the lack of controlled studies, but rather also a need for methodological plurality for better understanding the effects of yoga on current and former pediatric oncology patients.

The latest review on yoga in adult oncology patients was able to include 29 RCTs [27]. However, even with this comparably large number of RCTs, the authors stated the same methodological challenges we found: small and heterogeneous groups regarding diagnosis and treatments stage, different kind of interventions as well as different intervention length/ dose of intervention and no active control group that made comparability and determination of causality difficult. Similar reported methodological challenges were also echoed by Birdee and colleagues [28] in a systematic review of clinical applications of yoga in a general pediatric population that were able to include 19 RCTs (and 15 non-randomized controlled trials).

4.2. Methodological implications

However, an important aspect that may not yet have been sufficiently taken into account is that in the implementation and evaluation of such MBM studies, different active components may create a synergistic effect not captured in a cause-effect design [29]. Cause-effect relationships are therefore more difficult to investigate [30]. Furthermore, there is no consistently recognized definition of mindfulness [31], or one kind of yoga or meditation.

One way to take on this challenge may be to understand MBM interventions as complex interventions that should be evaluated using a combination of research method that is appropriate to the subject of research and the research question [32]. A combination of analysis of subjective data such as with qualitative interviews, observational data and patient reported outcomes (e.g. quality of life) [33] as well as objective data from psychometric (e.g. Body Perception Questionnaire [34]) and physiological measurements (e.g. heart rate variability) might be appropriate to map such a complex subject. As patients are already using MBM, feasibility and effectiveness studies that investigate how these interventions work in practice are needed to answer questions of safety and cost-benefit.

To investigate the underlying mechanism of the effect of yoga, meditation and mindfulness it might be helpful to identify the mutual neuro-psychological functions involved in these MBM interventions, such as interoception, focused attention, body awareness and emotional regulation [31,35]. Gibson [31] argues, that interoceptive awareness

(IA) – to be aware of our bodily sensations - might be the common component in mindfulness-based interventions. IA is related to neuroplasticity changes in the interoceptive network, in specific in the insular cortex [31]. A lot of neurocognitive and –psychological functions (e.g. attention & intention, body awareness & emotional awareness) are associated with this brain areas [36]. Although not fully understood this may give some insight towards the rational of how meditation, mindfulness and yoga practice could have a positive influence on both emotional and physical stress reaction.

Overall, yoga has already been well-studied in adult medicine with potential for targeted clinical application. For example, clinical data suggests that moderate depression can improve in association with improved biomarkers indicating a better neuroplasticity. Thus, yoga seems to set mechanisms in motion that promote the regenerative potential of processes in the CNS [37].

Even if we do not know the exact mechanisms of the effects of yoga and meditation in detail, MBM interventions likely have the potential to raise the positive therapeutic effects up on neuronal plasticity, brain oscillations or the proliferation of neuronal stem cells [38,39].

4.3. Implications for clinical practice

Combining results from systematic reviews in pediatric population with the findings in our review, the following implications can be drawn for the clinical application of yoga, meditation and mindfulness intervention within pediatric oncology:

Indicated by the review by Danhauer et al. [15] as well as our review findings, *Improvement in quality of life* is possible. This is considered one of the most important patient-reported outcomes in pediatric oncology and is related to higher patient satisfaction [33]. Supporting patients with an intervention that can be used autonomously in different situations and which is experienced as helpful in relation to various problems that arise from the treatment has the potential to greatly impact the quality of life, even in stressful situations such as facing oncological disease and the treatment [40,41].

Physical improvements, such as improved activity and fitness, flexibility and strength with yoga were able to be shown in both reviews on general pediatrics [8,28] as well as the subpopulation in the oncology review [15] and those reported here. Children and adolescents undergoing oncological treatment are faced with many (age-untypical) limitations of their physical capacity. They often feel weak, fatigued and nauseated. They are facing muscle loss due to bed restraint. Invasive procedures further restrict their mobility. Overall, yoga, mindfulness and meditation has proven to have a positive effect on interoceptive and body awareness [31,36]. In addition, yoga interventions are easy to adjust to the individual physical situation of the patient [9]. This combination makes them suitable even if the patient feel weak, has pain or is experiencing other side effects.

The ability to manage stress due to yoga may improve mental health generally with a special focus on the adaptive response to stress. Yoga, meditation and mindfulness is underlined by the increased parasympathetic output [8] and the reduction of blood pressure and respiratory rate, decreased tension and cortisol [28] improvement of immunological parameters [42] and a reduction of anxiety [8,15,28] that could be found in the general pediatric population as well as in pediatric oncology as reported here. Unquestionably facing a potentially life-threatening disease at a young age counts as such a major stress factor. Hence, being able to cope with and regulate such stress factors could have positive effects not only on mental but also on physical health and wellbeing.

5. Conclusion

The identified studies suggest that yoga, meditation and mindfulness might help to support children and adolescents during and after oncological treatment as they are non-invasive methods and address physical and emotional challenges caused by the disease and the treatment.

However, without higher case numbers that include control groups and an allocated randomization to systematically investigate the effects of yoga and mindfulness in children and adolescents with oncological diseases, we are unable to make conclusions about the efficacy of mind body therapies in pediatric oncology at this time.

The goal should be to combine different research methods that understand and evaluate MBM interventions such as yoga and mindfulness as complex interventions in order to appropriately study these therapies and add more clarity and reliability to assessments. Challenges to develop suitable research designs exist but would produce more clinical evidence and greater safety for these interventions.

CRediT authorship contribution statement

Wiebke Stritter: Conceptualization, Writing – original draft, Investigation, Organization, Planning, Coordination. **Janina Everding**: Writing – original draft, Investigation, Validation. **Jacqueline Luchte**: Conceptualization, Investigation, Writing – original draft. **Angelika Eggert**: Supervision, Resources, Manuscript editing. **Georg Seifert**: Supervision and initiation, Organization, Manuscript editing.

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Conflict of interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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