Palliative and Supportive Care

cambridge.org/pax

Original Article

Cite this article: Tanriverdi M, Cakir E, Akkoyunlu ME, Cakir FB (2022). Effect of virtual reality-based exercise intervention on sleep quality in children with acute lymphoblastic leukemia and healthy siblings: A randomized controlled trial. *Palliative and Supportive Care* **20**, 455–461. https://doi.org/10.1017/S1478951522000268

Received: 19 October 2021
Revised: 6 January 2022
Accepted: 20 February 2022

Key words:
Acute lymphoblastic leukemia; Exercise therapy; Pediatrics; Sleep disorders; Virtual reality

Author for correspondence:
Fatma Betül Cakir,
Pediatrics, Division of Pediatric Hematology Oncology, Bezmialem Vakif Universitesi Tip Fakultesi, Istanbul, Turkey.
E-mail: fbetulcakir@gmail.com

Effect of virtual reality-based exercise intervention on sleep quality in children with acute lymphoblastic leukemia and healthy siblings: A randomized controlled trial

Müberra Tanriverdi, P.T., PH.D.[1], Erkan Cakir, M.D.[2], Muhammed Emin Akkoyunlu, M.D.[3] and Fatma Betül Cakir, M.D.[4]

[1]Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Bezmialem Vakif University, Istanbul, Turkey; [2]Pediatric Pulmonology, Bezmialem Vakif University Faculty of Medicine, Istanbul, Turkey; [3]Department of Pulmonology, İstanbul Medipol University, Istanbul, Turkey and [4]Pediatric Hematology Oncology, Bezmialem Vakif University Faculty of Medicine, Istanbul, Turkey

Abstract

Objective. Sleep is one of the important measurements of the quality of life for children especially suffering from a chronic illness such as cancer. Our aim was to determine the changes in sleep quality and to investigate the effect of virtual reality-based exercise (VRBE) approaches on sleep in patients with acute lymphoblastic leukemia (ALL) off treatment.
Method. The participants (ALL and healthy siblings) were evaluated for sleep quality with polysomnography and "Children's Sleep Habit Questionnaire" before and after 12 weeks. The study randomized into two groups: an exercise group who received VRBE in two days in a week, 45 min of each session for 12 weeks and an control group who were managed with supportive measures. The VRBE comprised of aerobic exercise in four different games by Nintendo Wii Fit Plus®.
Results. This randomized controlled trial was carried out on 38 participants. Before intervention, ALL patients ($n = 24$) and healthy siblings ($n = 14$) had similar sleep quality in terms of polysomnography and Children's Sleep Habit Questionnaire findings. After intervention, total time asleep ($p = 0.023$), respiratory disturbance index of hypopnea ($p = 0.005$), apnea/hypopnea index ($p = 0.008$), and number of apnea ($p = 0.028$) statistically significant improved.
Significance of results. Patients with ALL off treatment had similar values of sleep quality with healthy siblings. Novel types of exercises like VRBE have positive effects on sleep disorders in children with ALL and also healthy siblings. Future studies are needed comparing the different types of interventions.

Introduction

Sleep plays a pivotal role both in the normal growth and development and also for the psychological well-being of healthy children (Rosen et al., 2008; Walter et al., 2015). Sleep disturbances are common in patients with cancer. The direct effect of cancer and the treatment modalities including, surgery, chemotherapy, radiotherapy, and hospitalizations, can all have a burden in the quality of sleep.

There are studies reporting sleep problems and disturbed quality of life during treatment for children with cancer (Hinds et al., 2007; Zupanec et al., 2010; van Litsenburg et al., 2011). On the other hand, these disturbances have the tendency to become chronic in the following months and years after treatment (Mulrooney et al., 2008; Gordijn et al., 2013; Cheung et al., 2017), and reported poor sleep quality in survivors of childhood cancer. Childhood Cancer Survivor studies reported survivors having more sleep difficulties and efforts to manage sleep than siblings (Mulrooney et al., 2008; Daniel et al., 2019).

Exercise is found to decrease levels of fatigue and improve quality of life in children with cancer (Hinds et al., 2007; Braam et al., 2010; Bauman et al., 2013; Beulertz et al., 2016). Although, there are conventional exercise intervention studies for children with cancer, most of these studies did not investigate sleep quality (Marchese et al., 2004; Braam et al., 2010; Speyer et al., 2010; Hartman et al., 2013; Müller et al., 2016; Mendoza et al., 2017; Howell et al., 2018; Kim and Park, 2019; Krull et al., 2020). Su et al. found no significant impact of exercise on sleep quality (Su et al., 2018). Orsey et al. reported greater physical activity was significantly associated with improved sleep quantity and efficiency in children with cancer (Orsey et al., 2013). However, there are no guidelines for standardized rehabilitative exercise for children with cancer (Braam et al., 2010; Speyer et al., 2010; Hartman et al., 2013). Adherence to periodic exercise is a serious problem (Morales et al., 2018).

Thus, integrating psychological interventions like games with exercise may be a valid alternative to maintain adherence and to ameliorate sleep problems. The Nintendo Wii® (Nintendo, Kyoto, Japan) is a virtual reality exercise game comprising activities consisting of 18 modes of yoga, 15 modes of resistance exercise, 16 modes of balance exercise, and 14 modes of aerobic exercise. The mean metabolic equivalent (MET) values of all activities were distributed over a wide range from 1.3 METs (Lotus Focus: balance exercise) to 5.6 METs (single-arm stand: resistance exercise). The MET values of the Nintendo Wii Fit Plus® versions of yoga and resistance exercise were similar to actual yoga (2.5 METs) and resistance exercise (3.0 METs). It enables a promising system for rehabilitation, and it is more enjoyable compared to conventional exercise therapy (Miyachi et al., 2010).

Our hypothesis is whether virtual reality exercise intervention increases sleep quality in children with ALL. Our aim is to investigate the effect of virtual reality exercise intervention using the Nintendo Wii Fit Plus® on sleep quality in children with acute lymphoblastic leukemia (ALL) in the years after completion of treatment who are in remission.

Methods

Study design

Our study was carried out with the ALL patients whose chemotherapy ended and are followed up by the department of pediatric hematology and oncology of our university hospital. Their healthy siblings were enrolled for comparison. Our local university ethics committee (23/302 numbered) was approved. Written informed consent and permission were obtained from participants and their parents. A prospective, randomized controlled study was conducted. The study randomized into two groups: an exercise group who received VRBE in two days in a week, 45 min of each session for 12 weeks and an control group who were managed with supportive measures. The flow chart of the ALL patients who met the inclusion criteria and were voluntarily included in the study was shown in Figure 1 (Schulz et al., 2010).

Participants

Acute lymphoblastic leukemia:

Inclusion criteria:

- Have a diagnosis of ALL
- The ages between 6 and 18 years
- Six months off treatment

Exclusion criteria:

- Having ongoing treatment
- Having a cranial irradiation
- Relapse of the disease
- Having any impairment in terms of barrier to the exercise

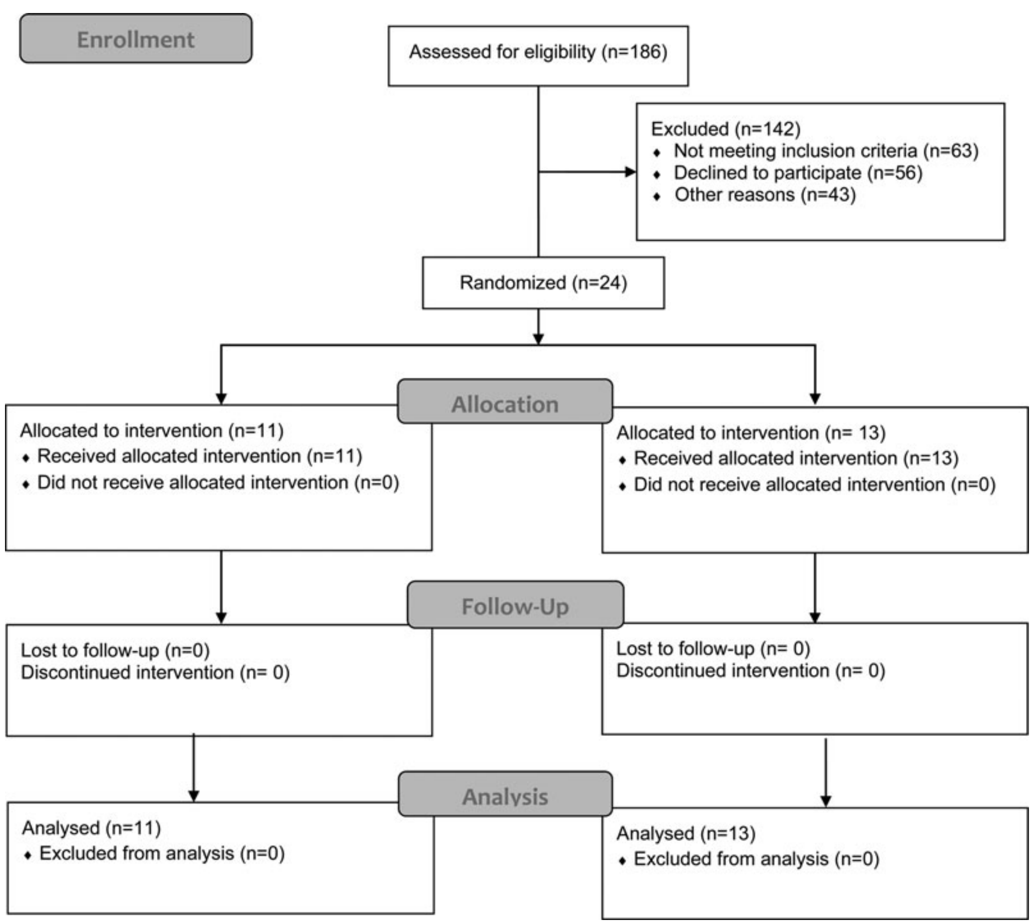

Fig. 1. Chart of participants with ALL (CONSORT 2010 flow diagram).

https://doi.org/10.1017/S1478951522000268 Published online by Cambridge University Press

Outcome measurements

The demographic, physical, and clinical characteristics of the participants were assessed with a questionnaire that included age (years), age at diagnosis (years), mom age (years), dad age (years), and body composition — height (m), weight (kg), and body mass index (kg/m^2).

Polysomnography

Written (sleep lab information sheet) informed consent and permission were obtained from participants and their parents before testing. All recordings started at the child's usual bedtime and ended at the usual time of getting up in the morning (between 09:30 pm and 06:00 am). School children were studied on days without school the next day. Nocturnal polysomnography (PSG) was recorded using Compumedics E-Series equipment (Compumedics, Abbotsford, Victoria, Australia). The examinations were conducted in accordance with the American Academy of Sleep Medicine (AASM) rules for technical performance and scoring of sleep (Beck and Marcus, 2009).

PSG is the gold standard method for recording sleep. It is the overnight sleep measurement that records brain waves, eye movement, muscle tension, respiration, heart rate, and leg movements. In this assessment, total time in bed (min), total time asleep (min), sleep onset delay, percent of sleep efficiency, events during sleep [stages 1, 2, and 3 (%) and REM (%)], least O_2 saturation, average of desaturation, respiratory disturbance index of hypopnea and REM, apnea/hypopnea index, number of apnea, and number of hypopnea were measured (Douglas et al., 1992).

Children's Sleep Habit Questionnaire

Children's Sleep Habit Questionnaire (CSHQ) was developed by Owens et al. (2000), and Turkish validity and reliability was made by Fiş et al. (2010). The scale determines the sleep habits and sleep-related problems. Bedtime resistance (items 1, 3, 4, 5, 6, and 8), sleep onset delay (item 2), sleep duration (items 9, 10, and 11), sleep anxiety (items 5, 7, 8, and 21), night wakings (items 16, 24, and 25), parasomnias (items 12, 13, 14, 15, 17, 22, and 23), sleep-disordered breathing (items 18, 19, and 20), and daytime sleepiness (items 26, 27, 28, 29, 30, 31, 32, and 33) are sub-titles of the scale. Parents are asked to recall sleep behaviors occurring over a "typical" recent week. Items are rated on a three-point scale: "usually = 3 points" if the sleep behavior occurred five to seven times per week; "sometimes = 2 points" for two to four times per week; and "rarely = 1 point" for zero to one time per week. Some items (1, 2, 3, 10, 11, and 26) were reversed in order to make a higher score indicative of more disturbed sleep. A cutoff total CSHQ score was determined 41 which was the best diagnostic confidence with the total score of CSHQ ranged between 0 and 135. Values above this score are considered to be "clinically significant" (Owens et al., 2000; Fiş et al., 2010).

Intervention

Participants were encouraged to participate in the exercise program by the pediatric hematologist/oncologist, and their continuity was followed up. The physiotherapist and the pediatric hematologist/oncologist collaborated in encouraging the participants and parents. In this study, we used the Nintendo Wii Fit Plus® game console including aerobic exercises to implement a virtual reality-based exercise (VRBE) program. After initial evaluations, a virtual reality-based game console exercise program was applied for 12 weeks with the randomly chosen ALL children and their siblings. The control group was not incorporated into the exercise program. The virtual reality-based games were *free jogging (3 METs)*, *hulo hoop (4 METs)*, *step (3 METs)*, and *step plus (3–4 METs)*. The aerobic exercises were chosen from Nintendo Wii Fit Plus® virtual reality games with the combination of exercise of different body regions. The exercise program was applied for two days in a week, 45 min of each session lasting 12 weeks. The PSG and CSHQ measurements were repeated after the exercise program. The initial PSG and CSHQ measurements of all ALL patients and healthy siblings were recorded. After 12 weeks, only the PSG and CSHQ measurements of the exercise group comprised of 11 ALL patients and 6 healthy siblings were recorded.

Statistical analysis

Data analyses were conducted using IBM SPSS Statistics for Windows (Version 22.0., Armonk, NY, USA). Standard statistical methods, including *t*-tests, Kappa statistics, and Pearson's correlation coefficients were used to compare groups and estimate relationships between variables. Due to high collinearity between all changers separately in regression models, we fit univariate and multivariate unconditional logistic regression models, calculating odds ratios (OR) and corresponding 95% CI, to identify the correlates. Tests of linear trend were calculated by fitting a variable representing ordinal categories of increasing exposure in the logistic models. We obtained a best-fitting multivariate logistic regression model, using a forward stepwise elimination procedure. All *p*-values presented are two-sided.

Sample size calculation for the study was based on the correlation coefficient that is expected to be detected the effect of exercise on PSG. Accordingly, sample size was determined as 10 subjects for each group to detect a relationship with 95% confidence level and 80% power (Orsey et al., 2013).

Results

Descriptive statistics

A total of 38 participants (24 ALL patients and 14 healthy siblings) were included in our study. Chemotherapy of the patients was finished at a mean of 33 ± 12.59 (min–max = 8–53) months. Participants were randomly chosen for the exercise and the control group (Figure 2). Baseline characteristics of participants are given in Table 1.

Outcomes measurements results

In terms of PSG, before exercise at initial evaluation, ALL patients and healthy siblings had a similar duration of sleep ($p = 0.871$). ALL patients were found to have no insomnia, no more time in bed than the healthy siblings ($p = 0.879$). ALL patients had similar sleep efficiency (the percent of time actually spent asleep; $p = 0.501$) as well as similar sleep onset delay ($p = 0.841$) and spent no more time awake during the night than those with healthy siblings. ALL patients and healthy siblings experienced similar levels of sleep stages [(stage 1 ($p = 0.327$), stage 2 ($p = 0.161$), stage 3 ($p = 0.073$), and REM sleep ($p = 0.667$)]. In terms of CSHQ results,

https://doi.org/10.1017/S1478951522000268 Published online by Cambridge University Press

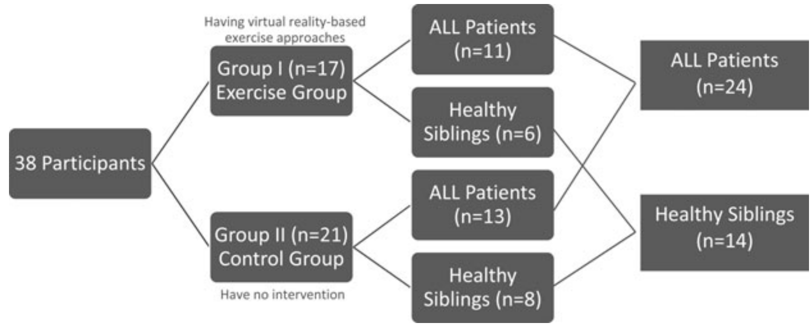

Fig. 2. Explanations and numbers of participants in groups with analyzed.

Table 1. Baseline characteristics of patients with ALL vs. healthy siblings

	ALL patients (n = 24)	Healthy siblings (n = 14)	p
Demographic characteristics			
Gender (boys/girls)	9/15	7/7	0.452
	Mean ± SD	Mean ± SD	
Age (years)	12.91 ± 5.79	13.33 ± 5.09	0.883
Age at diagnosis (years)	5.67 ± 4.92	—	—
Mom age (years)	38.70 ± 8.82	41.50 ± 9.14	0.554
Dad age (years)	40.60 ± 9.31	43.00 ± 8.65	0.617
Body composition			
Height (m)	147.55 ± 23.91	153.33 ± 26.50	0.463
Weight (kg)	40.05 ± 16.43	45.33 ± 17.97	0.315
Body mass index (kg/m^2)	17.46 ± 3.23	18.43 ± 3.59	0.453
CSHQ			
Bedtime resistance	9.09 ± 2.21	9.33 ± 3.67	0.634
Sleep onset delay	1.55 ± 0.69	1.83 ± 0.75	0.842
Sleep duration	6.09 ± 1.76	4.83 ± 1.33	0.255
Sleep anxiety	7.55 ± 2.42	6.17 ± 2.32	0.468
Night wakings	5.00 ± 1.61	5.00 ± 1.27	0.841
Parasomnias	8.91 ± 2.66	9.67 ± 2.25	0.715
Sleep-disordered breathing	4.00 ± 1.10	3.67 ± 1.21	0.694
Daytime sleepiness	15.27 ± 4.29	15.33 ± 4.63	0.813
Total score	57.46 ± 30.12	55.83 ± 29.28	0.710
Polysomnography			
Total time in bed (min)	392.94 ± 40.25	391.08 ± 14.36	0.879
Total time asleep (min)	312.33 ± 85.00	316.96 ± 63.50	0.871
Sleep onset delay	35.24 ± 40.45	32.38 ± 36.80	0.841
Sleep efficiency (%)	75.99 ± 23.43	81.18 ± 16.06	0.501
Events during sleep			
Stage 1 (%)	4.27 ± 3.60	3.13 ± 2.22	0.327
Stage 2 (%)	54.79 ± 10.71	49.63 ± 8.33	0.161
Stage 3 (%)	31.27 ± 11.99	38.76 ± 9.48	0.073
REM (%)	9.68 ± 7.30	8.48 ± 8.07	0.667
Least O_2 saturation	92.29 ± 2.26	90.75 ± 2.96	0.104
Average of desaturation	2.25 ± 1.14	2.40 ± 0.55	0.785
RDI of Hypopnea	3.51 ± 2.56	5.17 ± 6.07	0.278
RDI of REM	5.95 ± 7.20	5.30 ± 5.40	0.859
Apnea/hypopnea index	4.33 ± 4.68	3.57 ± 2.73	0.634
Number of apnea	20.87 ± 26.66	17.36 ± 16.22	0.896
Number of hypopnea	4.13 ± 6.84	1.71 ± 2.30	0.705

ALL, acute lymphoblastic leukemia; SD, standard deviation; CSHQ, Children's Sleep Habits Questionnaire; RDI, Respiratory Disturbance Index.

ALL patients and healthy siblings had similar bedtime resistance (p = 0.634), sleep onset delay (p = 0.842), sleep duration (p = 0.255), sleep anxiety (p = 0.468), night wakings (p = 0.841), parasomnias (p = 0.715), sleep disorders breathing (p = 0.694), and daytime sleepiness (p = 0.813).

After intervention results

The mean values of before and after intervention are shown in Table 2. The mean number of intervention session was 23.44 ± 1.41 (19–24). The adherence of the intervention was 97.67%. After exercise intervention, according to the PSG results, it is found that both ALL patients and healthy siblings had increased sleep efficiency as duration of sleep and improved percent of time spent asleep. Sleep efficiency improved statistically significantly in the exercise group after intervention. Among exercise groups, the respiratory disturbance index (RDI) of hypopnea, apnea/hypopnea index, and number of apnea improved significantly after intervention.

Discussion

In our study, the effect of VRBE approaches on the sleep quality of children with ALL and healthy siblings was investigated. We found no significant difference in sleep quality between ALL patients and the healthy siblings before exercise intervention. After exercise intervention, the VRBE intervention provided an improvement in sleep quality in both ALL patients and healthy siblings. Therefore, our hypothesis was consistent with the improvement of sleep quality after exercise intervention in both groups.

https://doi.org/10.1017/S1478951522000268 Published online by Cambridge University Press

Table 2. Mean values of the participants before and after intervention

	All participants									
	Exercise group ($n = 17$)							Control group ($n = 21$)		
	ALL patients ($n = 11$)			Healthy siblings ($n = 6$)			Between groups (Δ)	ALL patients ($n = 13$)	Healthy siblings ($n = 8$)	Between groups
	Before	After	*p*	Before	After	*p*	*p*	Mean	Mean	*p*
Polysomnography										
Total time in bed (min)	374.62	407.93	0.656	393.46	406.58	0.037*	0.239	390.52	445.65	0.147
Total time asleep (min)	304.94	377.64	0.244	285.90	329.80	0.623	0.023*	340.67	436.89	0.324
Sleep onset delay	35.44	21.50	0.146	52.30	30.40	0.271	0.108	29.41	38.67	0.371
Sleep efficiency (%)	81.03	89.06	0.081	72.78	80.96	0.624	0.84	86.27	79.35	0.960
Events during sleep										
Stage 1 (%)	3.52	3.77	0.630	4.08	3.06	0.736	0.530	3.64	2.96	0.834
Stage 2 (%)	57.20	64.60	0.584	53.50	70.42	0.810	0.136	60.65	50.24	0.170
Stage 3 (%)	30.62	22.05	0.258	34.72	22.24	0.533	0.320	26.84	24.47	0.416
REM (%)	8.66	9.57	0.923	7.66	4.30	0.192	0.530	8.41	22.33	0.524
Least O_2 saturation	91.66	92.42	0.481	90.20	89.40	0.516	0.505	92.16	90.10	0.271
Average of desaturation	2.40	2.00	0.526	2.00	3.00	0.465	0.157	2.24	2.56	0.978
RDI of hypopnea	3.10	1.97	0.012*	4.42	1.56	0.384	0.005**	2.87	3.94	0.488
RDI of REM	6.78	10.31	0.814	10.75	1.00	0.316	0.116	7.58	8.47	0.263
Apnea/hypopnea index	3.27	1.97	0.064	4.42	1.62	0.592	0.008**	2.65	3.52	0.921
Number of apnea	15.55	10.14	0.042*	18.00	10.00	0.077	0.028*	12.47	16.50	0.639
Number of hypopnea	2.55	2.28	0.418	3.00	0.25	0.707	0.291	2.36	2.47	0.956
Children's Sleep Habits Questionnaire[a]										
Bedtime resistance	9.09	8.00	0.000**	9.33	8.33	0.001**	0.001**	7.74	8.04	0.464
Sleep onset delay	1.54	1.27	0.007**	1.83	1.33	0.080	0.014*	1.27	1.60	0.714
Sleep duration	6.09	5.09	0.008**	4.83	4.33	0.040*	0.011*	4.55	4.23	0.533
Sleep anxiety	7.54	6.00	0.003**	6.16	6.01	0.092	0.007**	6.27	5.49	0.230
Night wakings	5.00	3.90	0.012*	5.00	4.83	0.003**	0.010**	4.50	4.25	0.388
Parasomnias	8.90	8.27	0.000**	9.66	9.16	0.001**	0.008**	8.95	8.94	0.148
Sleep-disordered breathing	4.00	3.45	0.005**	3.66	3.83	0.003**	0.096	3.50	3.47	0.230
Daytime sleepiness	15.27	12.27	0.035*	15.33	14.33	0.003**	0.003**	13.14	13.50	0.170
Total score	57.45	48.27	0.000**	55.83	52.33	0.004**	0.001**	49.23	49.52	0.452

ALL, acute lymphoblastic leukemia; RDI, Respiratory Disturbance Index.
[a]Higher score indicative of more disturbed sleep.
*$p < 0.05$.
**$p < 0.01$

There is no study that investigate the effect of exercise on the quality of life and sleep quality in children with ALL whose treatment was completed. Children with ALL have an improvement in sleep quality after about 3 years of treatment completion. Our study is unique in that we evaluated sleep quality by using VRBE intervention for 12 weeks. Exercise interventions were supervised by a physiotherapist with a multidisciplinary team.

There are conventional exercise intervention studies for children with cancer that include walking, swimming, jogging, biking, or mixed exercise (Marchese et al., 2004; Braam et al., 2010; Speyer et al., 2010; Hartman et al., 2013; Müller et al., 2016; Mendoza et al., 2017; Howell et al., 2018; Su et al., 2018; Kim and Park, 2019; Krull et al., 2020). Mendoza et al. enrolled 60 adolescent cancer survivors after 1-year off therapy in a wearable physical activity-tracking program for a 10-week period. They found some modest differences for subscales of QoL and their motivation improved for physical activity with a peer-based virtual support group (Facebook group) (Mendoza et al., 2017). However, these studies did not investigate sleep quality change according to exercise interventions but mostly evaluated the change in physical fitness and quality of life. Braam et al., in their 12-week randomized controlled intervention trial, found no significant differences in terms of physical fitness and psychosocial function between the intervention group and the group receiving usual care just after intervention (Braam et al., 2018). Kim et al. conducted a 8-week intervention consisting of supervised play and exercise sessions two times per week in six childhood cancer survivors on health-related quality of life, post-traumatic growth, and physical strength levels. The participants performed joint exercises, independently, at home, on the five days that they were unable to participate in group exercises and found that muscle strength and total physical strength scores were statistically significantly improved (Kim and Park, 2019). Müller et al. evaluated a 4-week inpatient rehabilitation program in 150 children with cancer by using physical activity amount and the intensity of walking activity by way of StepWatch Activity Monitor and health-related quality of life. They found that immediate and sustainable increases in HRQoL are beneficial for improving psychosocial well-being, general recovery as well (Müller et al., 2016). Howell evaluated the efficacy of a web-delivered, physical activity intervention among adolescent survivors to increase moderate-to-vigorous physical activity and improve fitness, neurocognitive and health-related quality of life over 24-weeks. Handgrip strength, number of sit-ups and push-ups, neurocognitive function, and health-related quality of life outcomes improved in the intervention group (Howell et al., 2018). All these aforementioned intervention studies evaluated whether there is a change in physical activity, lean body mass or muscle strength, and health-related quality of life at the end of follow-up of exercise. They did not investigate the effect of exercise on sleep quality, specifically. Su et al. reported improved general fatigue but not sleep/rest fatigue after a six-week walking exercise in 10 children with cancer. They found no significant impact on sleep quality or QoL (Su et al., 2018). Beulertz et al. explored the effects of a six-month, group-based, therapeutic exercise program for children with cancer on motor performance, level of activity, and quality of life. They achieved significantly greater improvements in motor performance compared to cancer patients not participating in the program (Beulertz et al., 2016). Additionally, intervention participants were also able to increase their overall level of activity and emotional well-being but not reach statistical significance. Su et al. and Beulertz et al. investigated partly the effect of exercise on the quality of life but not on sleep. Similar to our study, Orsey et al. conducted a study and assessed sleep quality by actigraphy collected over seven days in 36 children with cancer under treatment and found poorer sleep quality than healthy controls. This is the only study in literature that we have found as investigating the effect of physical activity on the quality of sleep. They found that greater physical activity as recorded by actigraphy was associated with improved objective sleep variables such as sleep efficacy, efficiency, waking time after sleep onset, number of wake bouts, sleep time, and percentage sleep. Higher physical activity during the day was associated with improved sleep the same night. However, they also realized that improved sleep did not translate into improved physical activity the following day (Orsey et al., 2013). Thus, they found the outcome of good sleep quality does not last longer as a continuing effect. However, despite it was not a statistically significant effect on several sleep quality subscales in our study, after a 12-week exercise intervention, we found beneficial effects of exercise on sleep quality.

However, there is no study with virtual reality gaming systems as the exercise intervention and check for the quality of sleep on cancer patients. Additionally, we used PSG as the objective measurement of sleep quality. Kawada stated that PSG is the standard device to determine the cutoff value for children with cancer (Kawada, 2013). On the other hand, So et al. recommended the objective sleep elements and other influences of children's perceptions of sleep quality using linear and non-linear models. The measurement of sleep quality indexes might differ according to several parameters, and therefore there must be multiple measurements for the objective conclusion (So et al., 2021). Therefore, more than one night's sleep quality assessment would be appropriate. The one-night evaluation is the limitation of our study. In addition, there is not yet a common consensus in the literature on assessing sleep quality. In further studies, an objective evaluation tool should be found by revealing the superiority of different evaluations to each other.

Conclusions

Virtual reality-based game exercises are promising for rehabilitation and are more enjoyable compared to conventional exercise programs. In order to increase participation in exercise and ensure continuity, exercise programs consisting of up-to-date and motivational games should be used. Our study is original in this respect and will shed new light on the physical exercise programs for children with cancer. It is important to acquire exercises as behavioral skills in order to see the change in daily life activity and quality of life scales as an effect of the rehabilitation process. As a future perspective, we can recommend virtual reality game exercises also at home-based settings by themselves. VRBE games are safe for these children and can be given as a home-based program like telerehabilitation. Particularly, after the COVID-19 pandemic, telerehabilitation programs might be more popular.

Conflict of interest. There are no conflicts of interest.

References

Bauman FT, Bloch W and Beulertz J (2013) Clinical exercise interventions in pediatric oncology: A systematic review. *Journal of Pediatric Research* **74**, 366–374. doi:10.1038/pr.2013.123

Beck SE and Marcus CL (2009) Pediatric polysomnography. *Sleep Medicine Clinics* **4**, 393–406. doi:10.1016/j.jsmc.2009.04.007
Beulertz J, Prokop A, Rustler V, *et al.* (2016) Effects of a 6-month, group-based, therapeutic exercise program for childhood cancer outpatients on motor performance, level of activity, and quality of life. *Pediatric Blood & Cancer* **63**, 127–132. doi:10.1002/pbc.25640
Braam KI, van Dijk-Lokkart EM, Veening MA, *et al.* (2010) Design of the quality of life in motion (QLIM) study: A randomized controlled trial to evaluate the effectiveness and cost-effectiveness of a combined physical exercise and psychosocial training program to improve physical fitness in children with cancer. *Cancer* **10**, 624. doi:10.1186/1471-2407-10-624
Braam KI, van Dijk-Lokkart EM, Kaspers GJL, *et al.* (2018) Effects of a combined physical and psychosocial training for children with cancer: A randomized controlled trial. *BMC Cancer* **18**, 1–12. doi:10.1186/s12885-018-5181-0
Cheung YT, Brinkman TM, Mulrooney DA, *et al.* (2017) Impact of sleep, fatigue, and systemic inflammation on neurocognitive and behavioral outcomes in long-term survivors of childhood acute lymphoblastic leukemia. *Cancer* **123**, 3410–3419. doi:10.1002/cncr.30742
Daniel LC, Wang M, Mulrooney DA, *et al.* (2019) Sleep, emotional distress, and physical health in survivors of childhood cancer: A report from the childhood cancer survivor study. *Psycho-Oncology* **28**, 903–912. doi:10.1002/pon.5040
Douglas NJ, Thomas S and Jan MA (1992) Clinical value of polysomnography. *Lancet* **339**, 347–350. doi:10.1016/0140-6736(92)91660-Z
Fiş NP, Arman A, Ay P, *et al.* (2010) Çocuk uyku alışkanlıkları anketinin türkçe geçerliliği ve güvenilirliği. *Anatolian Journal of Psychiatry* **11**, 151–160.
Gordijn MS, van Litsenburg RR, Gemke RJ, *et al.* (2013) Sleep, fatigue, depression and quality of life in survivors of childhood acute lymphoblastic leukemia. *Pediatric Blood & Cancer* **60**, 479–485. doi:10.1002/pbc.24261
Hartman A, Hop W, Takken T, *et al.* (2013) Motor performance and functional exercise capacity in survivors of pediatric acute lymphoblastic leukemia. *Pediatric Blood & Cancer* **60**, 494–499. doi:10.1002/pbc.24243
Hinds PS, Hockenberry MJ, Gattuso JS, *et al.* (2007) Dexamethasone alters sleep and fatigue in pediatric patients with acute lymphoblastic leukemia. *Cancer* **110**, 2321–2330. doi:10.1002/cncr.23039
Howell CR, Krull KR, Partin RE, *et al.* (2018) Randomized web-based physical activity intervention in adolescent survivors of childhood cancer. *Pediatric Blood & Cancer* **65**, e27216. doi:10.1002/pbc.27216
Kawada T (2013) Physical activity and sleep by actigraphy in children with cancer. *Pediatric Blood & Cancer* **61**, 955.
Kim Y and Park S (2019) Feasibility and benefits of a combined programme of exercise and play for paediatric cancer survivors: A pilot study. *European Journal of Cancer Care* **28**, e13111. doi:10.1111/ecc.13111
Krull MR, Howell CR, Partin RE, *et al.* (2020) Protein supplementation and resistance training in childhood cancer survivors. *Medicine & Science in Sports & Exercise* **52**, 2069–2077. doi:10.1249/MSS.0000000000002345
Marchese VG, Chiarello LA and Lange BJ (2004) Effects of physical therapy intervention for children with acute lymphoblastic leukemia. *Pediatric Blood & Cancer* **42**, 127–133. doi:10.1002/pbc.10481
Mendoza JA, Baker KS, Moreno MA, *et al.* (2017) A fitbit and Facebook mHealth intervention for promoting physical activity among adolescent and young adult childhood cancer survivors: A pilot study. *Pediatric Blood & Cancer* **64**, e26660. doi:10.1002/pbc.26660
Miyachi M, Yamamoto K, Ohkawara K, *et al.* (2010) METs in adults while playing active video games: A metabolic chamber study. *Medicine & Science in Sports & Exercise* **42**, 1149–1153. doi:10.1249/mss.0b013e3181c51c78
Morales JS, Valenzuela PL, Rincón-Castanedo C, *et al.* (2018) Exercise training in childhood cancer: A systematic review and meta-analysis of randomized controlled trials. *Cancer Treatment Reviews* **70**, 154–167.
Müller C, Krauth KA, Gerß J, *et al.* (2016) Physical activity and health-related quality of life in pediatric cancer patients following a 4-week inpatient rehabilitation program. *Supportive Care in Cancer* **24**, 3793–3802. doi:10.1007/s00520-016-3198-y
Mulrooney DA, Ness KK, Neglia JP, *et al.* (2008) Fatigue and sleep disturbance in adult survivors of childhood cancer: A report from the Childhood Cancer Survivor Study (CCSS). *Sleep* **31**, 271–281. doi:10.1093/sleep/31.2.271
Orsey AD, Wakefield DB and Cloutier MM (2013) Physical activity (PA) and sleep among children and adolescents with cancer. *Pediatric Blood & Cancer* **60**, 1908–1913. doi:10.1002/pbc.24641
Owens JA, Spirito A and McGuinn M (2000) The Cildren's Sleep Habits Questionnaire (CSHQ): Psychometric properties of a survey instrument for school-aged children. *Sleep* **23**, 1043–1052.
Rosen GM, Shor AC and Geller TJ (2008) Sleep in children with cancer. *Current Opinion in Pediatrics* **20**, 676–681. doi:10.1097/MOP.0b013e328312c7ad
Schulz KF, Altman DG, Moher D, *et al.* (2010) CONSORT 2010 statement: Updated guidelines for reporting parallel group randomised trials. *Trials* **11**, 32. doi:10.1186/1745-6215-11-32
So CJ, Palmer CA, Gonzalez RD, *et al.* (2021) Which objective sleep elements predict children's perceptions of good sleep quality? A preliminary investigation based on polysomnography and actigraphy. *Sleep Health* **7**, 65–71. doi:10.1016/j.sleh.2020.07.001
Speyer E, Herbinet A, Vuillemin A, *et al.* (2010) Effect of adapted physical activity sessions in the hospital on health-related quality of life for children with cancer: A cross-over randomized trial. *Pediatric Blood & Cancer* **55**, 1160–1166. doi:10.1002/pbc.22698
Su HL, Wu LM, Chiou SS, *et al.* (2018) Assessment of the effects of walking as an exercise intervention for children and adolescents with cancer: A feasibility study. *European Journal of Oncology Nursing* **37**, 29–34. doi:10.1016/j.ejon.2018.10.006
van Litsenburg RR, Huisman J, Hoogerbrugge PM, *et al.* (2011) Impaired sleep affects quality of life in children during maintenance treatment for acute lymphoblastic leukemia: An exploratory study. *Health and Quality of Life Outcomes* **9**, 25. doi:10.1186/1477-7525-9-25
Walter LM, Nixon GM, Davey MJ, *et al.* (2015) Sleep and fatigue in pediatric oncology: A review of the literature. *Sleep Medicine Reviews* **24**, 71–82. doi:10.1016/j.smrv.2015.01.001
Zupanec S, Jones H and Stremler R (2010) Sleep habits and fatigue of children receiving maintenance chemotherapy for ALL and their parents. *Journal of Pediatric Oncology Nursing* **27**, 217–228. doi:10.1177/1043454209358890