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ORIGINAL ARTICLE

Feasibility of a combined supervised and home-based whole-body vibration intervention in children after inpatient oncological treatment

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Abstract

Purpose Reduced physical performance due to therapy-related dysfunctions in children diagnosed with cancer contributes to insufficient physical activity levels. It is therefore essential that relevant functions are restored. Whole-body vibration (WBV) training, a neuromuscular stimulating exercise intervention, could have the potential to target those functions adequately. Therefore, the aim of this study was to evaluate the feasibility of a combined supervised and home-based WBV intervention with children after inpatient oncological treatment.

Methods Eight children aged 6–21 years were included after cessation of their inpatient oncological treatment. They performed a 12-week WBV training including one supervised and two home-based sessions per week according to a standardized training protocol. Feasibility, adherence and compliance to the vibration protocol were documented. Subjective benefits and satisfaction were assessed using a questionnaire.

Results Study participants attended 84.03 ± 13.09% of WBV sessions. No serious adverse events occurred. Some patients reported side effects partially resulting in modifications of the vibration protocol by therapists. Almost all children regarded the intervention as beneficial.

Conclusion A combined supervised and home-based WBV intervention with children after inpatient oncological treatment is feasible and safe. The beneficial potential regarding relevant sensory and motor dysfunctions is now to be investigated.

Trial registration number and date of registration DRKS00014713 15.05.2018

Keywords WBV · Vibration training · Physical activity · Feasibility · Childhood cancer · Exercise

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Introduction

A major concern after pediatric cancer therapy is physical inactivity. Research has shown that childhood cancer survivors do not meet physical activity guidelines [1, 2] and have difficulties to reintegrate into physical activities in school and leisure time after medical treatment [3–5]. Adequate levels of physical activity however are imperative in terms of secondary disease prevention and children´s physical, psychological and social well-being [6, 7].

Next to a variety of barriers for participation in physical activity [8–10], an important reason for inactivity are physical performance limitations. As such, Rueegg et al. found that survivors with physical performance limitations are 1.4 times more likely not to reach healthy activity levels [11]. In terms of physical performance, however, children diagnosed with cancer present impaired functional mobility, reduced lower extremity strength/flexibility and inadequate balance and gait patterns [12–16].

To date, an increasing number of exercise interventions in pediatric oncology have proven to be feasible and safe [17–19]. However, there is no exercise intervention directly targeted at improving the above-mentioned limitations, although a recent review requests further rehabilitative work to specifically improve mobility [20]. Especially the impact over a lifetime of impaired functional mobility highlights the significance of finding adequate ways to improve these mobility impairments [20].

One exercise modality that seems promising is whole-body vibration (WBV) training [21]. WBV is described as a neuromuscular training method in which mechanical stimuli are transmitted to participants through a vibrating platform. While the underlying mechanisms are yet not well understood, the "tonic vibration reflex", a stimulation of the muscle spindles which induces reflexive muscle contractions, seems to play a major role [22]. According to previous studies, WBV has the potential to increase muscular and metabolic power as it was found to increase activation of the neuromuscular and cardiorespiratory system [e.g. 23,24]. In addition, WBV is known to generally improve physical performance [25]. It has been shown to be effective in terms of pain reduction and subjective reduction of symptoms in adult oncological patients with a neurologically confirmed peripheral neuropathy [26] and studies in pediatric oncology have shown the feasibility and preliminary beneficial effects of WBV interventions after cancer treatment [27, 28]. One of these studies performed a 1-year WBV intervention with childhood cancer survivors finding beneficial effects on bone density. However, this intervention performed two 10 min bouts of vibration daily at 32–37 Hz [27]. While those longer bouts of WBV have been administered in studies aiming to improve bone health [21, 27, 29–31], interval training has the potential to improve the above-mentioned limitations, such as muscle strength/mass, gait and balance control [21]—factors relevant in terms of mobility. One study in pediatric oncology has proven the feasibility of a WBV intervention applying interval WBV training [28]. While this study was performed now only once a week and all WBV sessions were supervised, we aimed to enhance efficiency by increasing the number of training sessions per week. In an effort to keep participation burden low, those two additional training sessions were performed at home. Thus, our study sought to evaluate the feasibility of a 12-week combined supervised and home-based WBV intervention for children after inpatient oncological treatment.

Methods

Study design

This exploratory study was approved by the ethics committee of the German Sport University in Cologne, registered at the German Clinical Trials Register (DRKS00014713) and performed according to the latest declaration of Helsinki. It was conducted from May 2018–April 2019 at the Children´s Hospital Amsterdamer Straße in Cologne, Germany. Study participants took part in a 12-week combined supervised and home-based WBV intervention.

Recruitment

The treating oncologist identified potential study participants according to the inclusion criteria defined below out of a pool of patients that had previously shown interest or participated in our physical activity programs. He also provided written medical consent and medical supervision during the entire study period. The sports scientist contacted the children and their parents or legal guardians to inform them about the aims and procedure of the study, clarify any questions and arrange an appointment for the first WBV session when written informed consent from study participants and legal guardians was obtained.

Program participants

Children diagnosed with cancer were eligible for study participation if (i) they were between 6 and 21 years of age, (ii) they had received chemotherapy, (iii) their acute medical treatment requiring inpatient hospital stays had been completed, (iv) they provided written informed consent from the legal guardian as well as a child-specific informed consent from the participant prior to study participation, (v) they received medical clearance of the treating oncologist prior to study participation and (vi) in case they had received an operation, their wound healing was completed. Additionally, participants were excluded (i) if they had further diseases associated with symptoms of chemotherapy-induced peripheral neuropathy (CIPN) or neuromuscular disabilities, (ii) if they received a palliative treatment, (iii) due to any other circumstance assessed by the treating oncologist that made participation impossible and (iv) according to the suggestions of the device manufacturer (pregnancy; acute thrombosis; implants in activated regions of the body; acute inflammation of the locomotor system; active arthrosis or arthropathy; acute tendinopathy in activated regions of the body; acute hernia; acute discopathy; fresh fractures in activated regions of the body; gallstones or stones in the urinary tract collection system; post-surgery wounds and fresh wounds in activated regions of the body or incomplete wound healing; rheumatoid arthritis and epilepsy).

Based on established relative contraindications [32] and results from our previous WBV intervention study [28], training was interrupted when children had thrombocytes under 30.000/µl, were experiencing acute thrombosis, nausea, vomiting, dizziness, fever (≥ 38.0°) or severe infections. Moreover, training had to be interrupted up to 7 days after minor surgical procedures (except lumbar puncture and bone marrow puncture) and for at least 14 days after major surgical procedures or when participants had muscle/tendon/ligament/bone or joint injuries that would prevent participation temporarily.

Intervention

During the 12-week WBV intervention, study participants exercised three times per week on a side-alternating vibration platform (Galileo® Med Advanced, Novotec Medical GmbH, Pforzheim, Germany). During week one (familiarization period), two WBV sessions were supervised by an exercise professional (1 × at the Children´s Hospital Amsterdamer Straße, 1 × at home). During the following weeks (week 2–12), one WBV session per week was performed supervised at the Children´s Hospital while two sessions were performed at home. To allow for sufficient time to recover, we advised the participants and their parents to keep at least one day of recovery between two training sessions.

The applied vibration protocol was developed based on our previous study [28]. It contained 6–16 min of overall vibration time including a 60 s warm-up (18 Hz, 2-mm peak-to-peak-displacement) followed by 5–10 vibration segments (individually adjusted by the participants based on their daily shape) of 60–90 s (18–27 Hz according to defined progression in Fig. 1, 2-mm peak-to-peak-displacement) with 60 s rest in between resulting in 11–26 min of session duration. The variability of repetitions was integrated to allow individualization of training sessions (especially at home) according to participant's day's condition. Study participants were encouraged to perform as many repetitions as possible without feeling physically overstrained. (Of note: Progression was aspired by increasing duration of vibration segments and exercise frequency, not by increasing the number of repetitions over time). While exercising, study participants stood in a forefoot position with knees and hip slightly bent or performed dynamic exercises (i.e. dynamic squats, squatting position, tiptoeing). For safety reasons, the supervising exercise professional or the participant´s parent stabilized the child if necessary.

Assessments

The primary study outcome was feasibility, defined as the ability to participate in supervised and home-based WBV training sessions without occurrence of any WBV-related serious adverse events leading to a health deterioration necessitating study cessation (study drop-out). To ensure detection of serious adverse events, all study participants were verbally and in writing informed to contact the sports scientist and/or treating physician immediately in case of severe pain, discomfort or other abnormalities during or after WBV training. In addition, WBV-related side effects were recorded after each supervised exercise session recapturing the previous training week using a documentation sheet. Study participants were asked whether/how strong they felt any tingling, itchiness, burning sensation, pain, sore muscles or any other discomfort on a scale from 1 to 5.

A second documentation sheet was used to record adherence and reasons for non-participation. Participation rate was calculated for all training sessions, as well as divided into supervised training sessions at the hospital and unsupervised training sessions at home as the (number of sessions

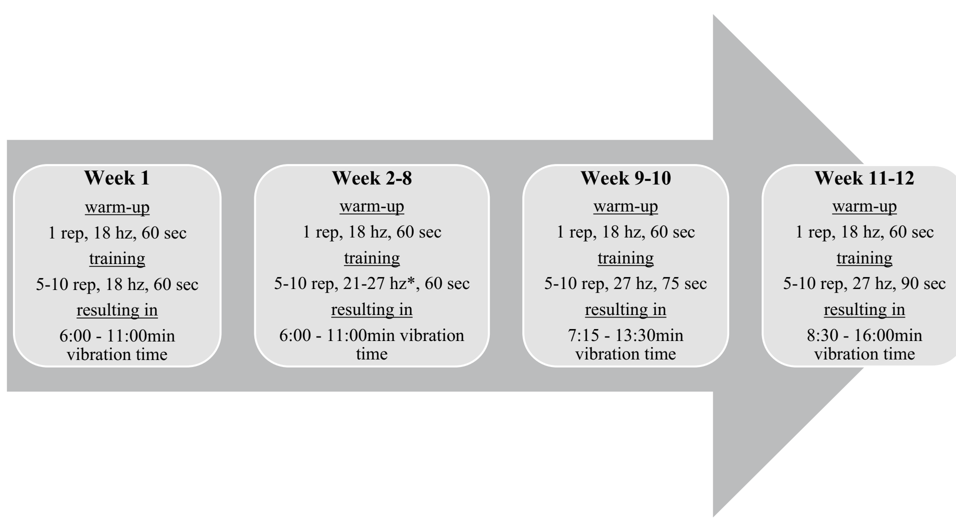

Fig. 1 Defined vibration protocol. *hz* (exercise) frequency (hertz), *min* minutes, *rep* repetitions, *sec* seconds. *Increase of exercise frequency by 1 Hz per week

participated/number of sessions offered)*100. Reasons for not participating were categorized and listed in the order of the highest frequency (%).

To evaluate the compliance to the vibration protocol, study participants documented vibration frequency, duration of vibration segments and number of repetitions on the vibration platform. Compliance to the vibration protocol is reported as the final step achieved (each week represents one step), average number of repetitions, average minutes of vibration and average duration of training sessions.

A self-developed questionnaire which has been described previously [28] was used to determine patients' and parents' satisfaction with the WBV intervention. The questionnaire included 14 (resp. 15 in parent-version) closed-ended (5-point likert scale) questions on 3 dimensions (perceived physical effectiveness of WBV training, personal attitude towards WBV training, satisfaction with home-based training).

Data analysis

Descriptive analysis was conducted to characterize the study sample and evaluate parameters of feasibility, adherence, compliance to the training protocol and satisfaction with the intervention. Descriptive statistical parameters and frequencies were calculated using IBM SPSS Statistics 26.

Results

Study sample

Eight children diagnosed with cancer who had completed all inpatient medical treatment were included. They were 11.44 ± 3.45 years old and were diagnosed 3.19 ± 1.86 years prior to study inclusion with different cancer diseases (acute lymphoblastic leukemia (ALL) (n = 2), rhabdomyosarcoma (n = 2), neuroblastoma (n = 1), glioblastoma multiforme (n = 1), anaplastic pleomorphic xanthoastrozytoma (n = 1), Non-Hodgkin B-cell lymphoma (B-NHL) (n = 1)). They had received either chemotherapy (25%), chemotherapy and operation (25%) or a combination of chemotherapy, radiotherapy and an operation (50%). Study participants completed their last inpatient treatment 2.67 ± 1.78 years prior to study participation. Six participants received maintenance therapy of which one was still ongoing during the study period (Table 1).

Table 1 Characteristics of study participants (N = 8)

Age, years	
Mean ± SD (mdn)	11.44 ± 3.45 (11.05)
[min – max]	[6.58–17.5]
Gender	
Female	n = 5 (62.5%)
Male	n = 3 (37.5%)
Diagnoses	
ALL	n = 2 (25%)
Rhabdomyosarcoma	n = 2 (25%)
Neuroblastoma	n = 1 (12.5%)
Glioblastoma multiforme	n = 1 (12.5%)
Anaplastic pleomorphic xanthoastrozytoma	n = 1 (12.5%)
B-NHL	n = 1 (12.5%)
Time since last oncological diagnosis, years	
Mean ± SD (mdn)	3.19 ± 1.86 (3.34)
[min – max]	[0.75–5.83]
Medical treatment	
Chemotherapy	n = 2 (25%)
Chemotherapy and operation	n = 2 (25%)
Chemotherapy, operation and radiotherapy	n = 4 (50%)
Time since cessation of last inpatient medical treatment, years	
Mean ± SD (mdn)	2.67 ± 1.78 (2.88)
[min – max]	[0.33–5.25]
Maintenance treatment	
Yes	n = 6 (75%)*
No	n = 2 (25%)

max maximum, *mdn* median, *min* minimum, *n* sample size, *SD* standard deviation

*one study patient received maintenance treatment during the study period

Feasibility

No serious adverse events leading to health deterioration and, thus study drop-out occurred during the study period. However, one child had to interrupt WBV training for one week due to pain in the Achilles tendon. In addition, two patients were not able to complete the minimum of 5 repetitions during one training session each, due to pain in the feet (n = 1) resp. very strong itching in the calves (n = 1). One child had to reduce vibration frequency due to strong burning sensation. During study participation, 7/8 study participants reported tingling resp. itchiness, 6/8 pain, 5/8 muscle soreness and 2/8 burning sensation during resp. after WBV training. While tingling was mentioned most frequent (5.86 ± 3.89 weeks), itchiness (4.43 ± 2.94 weeks), muscle soreness (3.60 ± 1.67 weeks) and pain (2.67 ± 1.51 weeks) were documented less frequent, followed by burning sensation which was documented in 1.50 ± 0.71 weeks. On a scale from 1 to 5, burning sensation was rated most disturbing (3.25 ± 1.77), followed by itchiness (2.77 ± 0.89), tingling (2.75 ± 1.15) and pain (2.51 ± 1.38), while muscle soreness was rated lowest (2.11 ± 0.49) (Table 2). In addition, study participants mentioned fatigue, heavy/tired legs, sensation

Table 2 Occurrence of side effects (number of weeks during which each side effect was mentioned) and it´s average intensity on a scale from 1 (low) to 5 (high) documented on a weekly basis

	Tingling [no. of weeks (intensity)]	Itchiness [no. of weeks (intensity)]	Burning sensation [no. of weeks (intensity)]	Pain [no. of weeks (intensity)]	Muscle soreness [no. of weeks (intensity)]
P1	6 (2.50)	6 (2.13)	/	2 (2.25)	/
P2	1 (1.00)	/	/	4 (2.88)	4 (1.75)
P3	/	1 (2.50)	/	/	6 (1.92)
P4	9 (3.92)	2 (1.75)	2 (2.00)	4 (1.19)	2 (2.75)
P5	10 (2.20)	7 (2.50)	/	1 (1.00)	4 (1.63)
P6	10 (2.48)	1 (4.50)	1 (4.50)	1 (3.00)	/
P7	2 (4.50)	7 (3.07)	/	4 (4.75)	/
P8	3 (2.67)	7 (2.93)	/	/	2 (2.50)
Total (No. of weeks) [mean ± SD (mdn); min–max]	5.86 ± 3.89 (6.00) 1.00–10.00	4.43 ± 2.94 (6.00) 1.00–7.00	1.50 ± 0.71 (1.50) 1.00–2.00	2.67 ± 1.51 (3.00) 1.00–4.00	3.60 ± 1.67 (4.00) 2.00–6.00
Total (Intensity) [mean ± SD (mdn); min–max]	2.75 ± 1.15 (2.50) 1.00–4.50	2.77 ± 0.89 (2.50) 1.75–4.50	3.25 ± 1.77 (3.25) 2.00–4.50	2.51 ± 1.38 (2.56) 1.00–4.75	2.11 ± 0.49 (1.92) 1.63–2.75

max maximum, *mdn* median, *min* minimum, *no* number, *P* participant, *SD* standard deviation

of pressure in feet/lower legs, numbness in legs and strong trembling as other side effects of WBV training.

Adherence

Study participants completed 84.03 ± 13.09% (Median: 86.11%) of WBV sessions. Adherence during supervised exercise sessions was 87.50 ± 13.36% (Median: 91.67) and 81.25 ± 15.91% (Median: 85.42) during home-based sessions. Reasons for non-participation were medical issues (50.00%), holidays (23.91%), not specified (10.87%), no time (8.70%), no motivation (6.52%).

Compliance to the vibration protocol

While 4/8 (50%) study participants were able to complete the entire vibration protocol (27 Hz, 90 s) as defined in Fig. 1, 2/8 (25%) reached step 7 (week 7, 26 Hz,60 s), 1/8 (12.5%) reached step 9 (week 9, 27 Hz, 75 s) and 1/8 reached step 10 (week 10, 12.5%) (27 Hz, 75 s). The average number of repetitions was 6.62 ± 0.67 (1–15 repetitions). The average duration of vibration time was 7.61 ± 0.68 min (2–16 min) and the average length of WBV sessions was 14.29 ± 1.36 min (3–31 min).

Satisfaction with the WBV intervention

Based on questionnaires, study participants perceived positive effects of the WBV intervention in terms of strength (feet: 4/7; legs: 6/7) and mobility (move better: 4/8; walk/run better: 4/7). Some parents agreed upon this impression (stronger feet: 2/5; stronger legs: 3/5; move better: 4/7; run/walk better: 3/6), while others were unsure. Participants and parents described the intervention to be fun (5/8; 6/8) and most children (5/8) and 3/8 parents stated that the WBV training was motivating. Only two children and one parent perceived this intervention to be boring or the WBV sessions to cause discomfort (1/8 resp. 1/7). While only 1/8 children rated the training duration to be too long, this was mentioned by 50% (4/8) of their parents. On the other hand, only 1/8 parents evaluated the intervention to be physically demanding while 7/8 children did so. Regarding the home-based training, 7/7 parents and most children (6/8) felt safe with home-based exercising and no parent stated that stronger supervision/help would have been necessary. Children answered that they complied with their parents´ instructions (7/8), which was supported by parents´ impression (5/7). In addition, most children (6/8) and all parents (8/8) agreed that the home-based part reduced time constraints because of less travel time. Nevertheless, only 3/8 children and 3/8 parents would have liked to continue the home-based program (Table 3).

Discussion

This study reveals that a combined supervised and home-based WBV intervention is feasible with children after inpatient oncological treatment. Study participants and their parents felt well able, safe and confident to exercise at home.

Table 3 Questionnaire data on satisfaction with the WBV intervention reported by study participants and parents

		Disagree n (%)	Some-what, disagree n (%)	Neutral n (%)	Some-what, agree n (%)	Agree n (%)	I don't know n (%)
Perceived physical effectiveness of WBV training							
WBV training made my/my child`s feet feel stronger	Children (n = 8)	n = 1 (12.5)	n = 0 (0.0)	n = 2 (25.0)	n = 2 (25.0)	n = 2 (25.0)	n = 1 (12.5)
	Parents (n = 8)	n = 0 (0.0)	n = 2 (25.0)	n = 1 (12.5)	n = 2 (25.0)	n = 0 (0.0)	n = 3 (37.5)
WBV training made my/my child`s legs feel stronger	Children (n = 8)	n = 0 (0.0)	n = 0 (0.0)	n = 1 (12.5)	n = 1 (12.5)	n = 5 (62.5)	n = 1 (12.5)
	Parents (n = 7)	n = 0 (0.0)	n = 1 (12.5)	n = 1 (12.5)	n = 3 (37.5)	n = 0 (0.0)	n = 2 (25.0)
I/my child was able to move better	Children (n = 8)	n = 1 (12.5)	n = 0 (0.0)	n = 3 (37.5)	n = 3 (37.5)	n = 1 (12.5)	n = 0 (0.0)
	Parents (n = 8)	n = 1 (12.5)	n = 2 (25.0)	n = 0 (0.0)	n = 2 (25.0)	n = 2 (25.0)	n = 1 (12.5)
I/my child was able to walk/run better	Children (n = 8)	n = 2 (25.0)	n = 0 (0.0)	n = 1 (12.5)	n = 2 (25.0)	n = 2 (25.0)	n = 1 (12.5)
	Parents (n = 8)	n = 2 (25.0)	n = 1 (12.5)	n = 0 (0.0)	n = 1 (12.5)	n = 2 (25.0)	n = 2 (25.0)
Personal attitude towards WBV training							
WBV training was fun	Children (n = 8)	n = 0 (0.0)	n = 1 (12.5)	n = 2 (25.0)	n = 2 (25.0)	n = 3 (37.5)	n = 0 (0.0)
	Parents (n = 8)	n = 0 (0.0)	n = 1 (12.5)	n = 1 (12.5)	n = 3 (37.5)	n = 3 (37.5)	n = 0 (0.0)
WBV training was motivating	Children (n = 8)	n = 0 (0.0)	n = 1 (12,5)	n = 2 (25.0)	n = 4 (50.0)	n = 1 (12.5)	n = 0 (0.0)
	Parents (n = 8)	n = 1 (12.5)	n = 0 (0.0)	n = 4 (50.0)	n = 2 (25.0)	n = 1 (12.5)	n = 0 (0.0)
WBV training was boring	Children (n = 8)	n = 4 (50.0)	n = 2 (25.0)	n = 0 (0.0)	n = 2 (25.0)	n = 0 (0.0)	n = 0 (0.0)
	Parents (n = 8)	n = 3 (37.5)	n = 2 (25.0)	n = 2 (25.0)	n = 1 (12.5)	n = 0 (0.0)	n = 0 (0.0)
WBV training was physically demanding	Children (n = 8)	n = 0 (0.0)	n = 1 (12.5)	n = 0 (0.0)	n = 6 (75.0)	n = 1 (12.5)	n = 0 (0.0)
	Parents (n = 8)	n = 0 (0.0)	n = 3 (37.5)	n = 4 (50.0)	n = 1 (12.5)	n = 0 (0.0)	n = 0 (0.0)
WBV training felt discomfortable	Children (n = 8)	n = 5 (62.5)	n = 2 (25.0)	n = 0 (0.0)	n = 1 (12.5)	n = 0 (0.0)	n = 0 (0.0)
	Parents (n = 8)	n = 3 (37.5)	n = 2 (25.0)	n = 1 (12.5)	n = 1 (12.5)	n = 0 (0.0)	n = 1 (12.5)
WBV training duration was too long	Children (n = 8)	n = 6 (75.0)	n = 0 (0.0)	n = 1 (12.5)	n = 1 (12.5)	n = 0 (0.0)	n = 0 (0.0)
	Parents (n = 8)	n = 2 (25.0)	n = 2 (25.0)	n = 0 (0.0)	n = 3 (37.5)	n = 1 (12.5)	n = 0 (0.0)
Satisfaction with home-based training							
I felt safe with supervision of my parents/ while supervising my child	Children (n = 8)	n = 0 (0.0)	n = 0 (0.0)	n = 2 (25.0)	n = 0 (0.0)	n = 6 (75.0)	n = 0 (0.0)
	Parents (n = 8)	n = 0 (0.0)	n = 0 (0.0)	n = 0 (0.0)	n = 4 (50.0)	n = 3 (37.5)	n = 1 (12.5)
I would have needed stronger supervision/help through exercise professionals	Children (n = 0)	N/A	N/A	N/A	N/A	N/A	N/A
	Parents (n = 8)	n = 7 (87.5)	n = 1 (12.5)	n = 0 (0.0)	n = 0 (0.0)	n = 0 (0.0)	n = 0 (0.0)
Home based training reduced time constraints because of less travel time	Childre*n* (n = 8)	n = 1 (12.5)	n = 0 (0.0)	n = 1 (12.5)	n = 0 (0.0)	n = 6 (75.0)	n = 0 (0.0)
	Parents (n = 8)	n = 0 (0.0)	n = 0 (0.0)	n = 0 (0.0)	n = 1 (12.5)	n = 7 (87.5)	n = 0 (0.0)
I/ my child complied with the instructions my parents/ I gave	Children (n = 8)	n = 0 (0.0)	n = 0 (0.0)	n = 1 (12.5)	n = 1 (12.5)	n = 6 (75.0)	n = 0 (0.0)
	Parents (n = 8)	n = 0 (0.0)	n = 0 (0.0)	n = 2 (25.0)	n = 2 (25.0)	n = 3 (37.5)	n = 1 (12.5)
I would enjoy to continue home-based training (with my child)	Children (n = 8)	n = 1 (12.5)	n = 3 (37.5)	n = 1 (12.5)	n = 1 (12.5)	n = 2 (25.0)	n = 0 (0.0)
	Parents (n = 8)	n = 2 (25.0)	n = 1 (12.5)	n = 2 (25.0)	n = 0 (0.0)	n = 3 (37.5)	n = 0 (0.0)

n sample size

This idea is supported by recent reviews finding that WBV intervention studies including home-based components are feasible in children with disabilities [21, 31]. Additional home-based components could be a beneficial adjunct [33] as they reduce time constraints due to less travel time. As such, home-based components may enhance training frequency potentially resulting in higher efficiency while keeping participation burden low and may also be a preferred setting of children after cessation of treatment in case space and equipment is available [10]. Nevertheless, supervised exercise interventions have been found to have higher adherence [18]. Although this was also the case during this study, both participation rates were generally high with > 80% compared to WBV intervention studies in children with disabilities and general exercise programs in pediatric oncology [18, 21]. Recruiting study participants out of a pool of patients that had previously shown interest or participated in our physical activity programs may have had a positive effect on adherence, as study participants were generally interested in physical activity and had or developed a positive relationship to the supervising sports therapist.

The feasibility of our combined supervised and home-based WBV intervention was also demonstrated by the fact that no serious adverse events leading to health deterioration and/or study drop-out occurred. However, a variety of WBV-related side effects was documented. The most frequent ones were tingling and itchiness. Those are possible reactions to WBV that have been described before [25]. Interruption of the intervention, as well as reduction of repetitions or training frequency were necessary four times due to strong pain, itchiness and burning sensation. Similar modifications of WBV protocols have already been implemented in our previous study [28]. The high number of patients mentioning pain at least once during the study period and the additional side effects, such as the sensation of pressure and numbness, must be considered. Pain in the Achilles tendon has been mentioned before in the context of WBV training in pediatric oncology [28] and might be due to reduced ankle function, while pain in feet/legs, sensation of pressure and numbness could also be related to CIPN [34]. To help clarify urgent questions, for example, about occurred side effects immediately and to improve early detection of medical issues or training mistakes an additional contact (i.e. via phone) after each home-based session could be useful. Furthermore, parents should strongly be encouraged to stop exercising in case of pain, discomfort or uncertainty during home-based sessions. Especially due to the fact that the named side effects occur rather frequently, it might also be helpful to inform children and parents about potential side effects on a larger scale prior to the WBV training to prevent insecurity and concerns.

Despite the above-mentioned adaptations to the training protocol, all study participants were able to exercise at least at 26 Hz, the second-highest frequency defined in our WBV protocol. While frequencies above 20 Hz are recommended in side-alternating systems to improve muscular performance [35], Ritzmann et al. (2013) found higher frequencies to be related to a higher neuromuscular activation [36]. However, they and most studies analyzing the effect of WBV in children with disabilities have administered frequencies no higher than 30 Hz [21, 31, 36], which is also recommended by the device manufacturer [35]. That this training intensity seems sufficient is underlined by the fact, that almost all children perceived the intervention to be physically demanding. This might indicate that WBV is strongly challenging for the neuromuscular system and that children after cancer treatment suffer from early neuromuscular fatigue. At the same time, only one parent rated the intervention to be exhausting for his/her child. While parents usually present an overprotecting attitude after pediatric oncological treatment, the short session duration, the static training position and the passive training modality do not make an exhausting impression. This emphasizes again the importance of close supervision and extensive information about the principles, mechanisms and intensity of WBV training if exercising in home-based settings.

Moreover, the possibility to choose between 5 and 10 repetitions seems to be a reasonable way to adapt training intensity to the day´s physical condition of study participants. This choice resulted in an average duration of WBV sessions of 14.29 ± 1.36 min, which has been recommended previously [31].

Overall, study participants were satisfied with the WBV intervention and rated it to be fun and motivating. However, 50% did not wish to continue the home-based program after 12 weeks. A 12-week time frame is typical in the field of exercise intervention studies in pediatric oncology [18] and WBV interventions with children with disabilities were also often conducted over a 6–12-week period. Therefore, our aim was to evaluate the feasibility of WBV over a similar time period with children after inpatient medical treatment, as well. Considering that this intervention was feasible and that benefits of WBV on muscle power were found in two studies after 6–12 weeks without any further improvement beyond this [25], a 12-week program seems reasonable. Nevertheless, the effectiveness of a combined supervised and home-based WBV intervention in pediatric oncology is still to be investigated. While study participants and their parents reported perceived physical improvements, data on physical effectiveness of WBV with childhood cancer patients remain to be elucidated [28]. Overall, WBV is an intensive exercise modality requiring little time. However, the social benefits that group exercise programs may provide [7] should also be considered. Therefore, WBV may be an effective adjunct to general (group-based) exercise opportunities.

The results are limited because of the very small study sample, due to the exploratory nature of this study. In addition, the study sample was heterogeneous; besides the variety of cancer diagnoses, especially the time since last inpatient medical treatment covered a wide range. Side effects were assessed recapturing the previous training week which might influence accuracy of information given. In addition, no very detailed information about location of side effects that have arisen or additional physical activities potentially influencing/causing occurrence of muscle soreness or pain were analyzed.

Conclusion

As a conjunct to the current literature, this study suggests that a combined home-based and supervised WBV intervention aiming at improved mobility is feasible with children after inpatient oncological treatment. Due to reduced participation burden the additional home-based WBV sessions may allow to enhance training frequency probably resulting in higher efficiency while keeping participation burden low.

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Availability of data and material The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

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

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of the German Sport University Cologne (Date 26.02.2018 /No. 021/2018).

Consent to participate Informed consent was obtained from all individual participants included in the study and their legal guardians.

Consent for publication Patients signed informed consent regarding publishing data anonymously.

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