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Examination of The Applicability and Intensity of Nintendo Wiitm Exergaming For Children With Acute Lymphoblastic Leukemia: A Preliminary Study

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ABSTRACT

Aims: Exploring the applicability and intensity of exergaming for children with cancer is essential. This study aimed to examine the applicability of Nintendo Wii™ exergames and determine the intensity of Physical Activity (PA) provided by these exergames for children with acute lymphoblastic leukemia.

Methods: In this preliminary study, 31 children aged 6-14 years of both sexes were asked to play Wii exergames for a 60-minute research session. Using the Arabic video game applicability questionnaire, the children were instructed to score seven statements regarding usability, engagement, and enjoyment of exergames. In addition, heart rate (HR), predicted heart rate maximum (pred. HRmax), rating of perceived exertion (RPE), and oxygen saturation (SpO₂) were measured at baseline and every 15 min during the session.

Results: About 74.2%, 83.9%, and 93.6% of the children agreed that the games were usable, engaging, and enjoyable, respectively. Exergames were of moderate intensity as the children reached 59.22 ± 8.40 % of age-predicted HRmax: the HR and its percentage of increase from the pred. HRmax (% pred. HRmax) was significantly higher in girls than in boys ($P=0.01$). The level of perceived exertion was moderate (5.74 ± 0.63).

Conclusion: Implementation of Nintendo Wii exergames for 60 minutes was found to be applicable. In addition, it resulted in PA of moderate intensity.

Keywords: Acute lymphoblastic leukemia; Exergaming; video games Nintendo Wii™; children; childhood cancer; rehabilitation.

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INTRODUCTION

Acute lymphoblastic leukemia (ALL) is a malignant uncontrolled alteration and proliferation of lymphoblasts in the bone marrow, blood, and extramedullary sites. It is the most common type of childhood cancer [1]. Chemotherapy and radiotherapy cause long-term health and function effects, including impairments in exercise tolerance, characterized by decreased aerobic and anaerobic fitness, muscular strength, neuromuscular coordination, balance, and flexibility [2]. Therapy side effects such as nausea, excessive exhaustion, anemia, immunosuppression, and the length of hospitalization indirectly impact a patient's ability and willingness to be physically active throughout treatment.³

Physical activity (PA) has been associated with various physiological and psychological health benefits for life.² It affects cancer-associated symptoms positively.⁴ An emerging trend in promoting PA is exergaming, active or interactive video gaming, where exercise and video games intersect [5, 6]. Nintendo Wii™ is one of the consoles that provide a gaming style that enables interaction through motion sensors [7].

Wii Fit was successfully used with children to promote function in different health conditions like developmental delay, cerebral palsy, autism, cystic fibrosis, Raynaud disease, and migraine [8]. Psychological enhancements such as increased enjoyment, distraction, and socialization were the benefits of exergaming in children with cancer.⁷ Exergaming is a choice of intervention health professionals use to promote physical and psychological aspects of health [9]. Yet the literature has not thoroughly examined the parameters and guidance of such intervention.

Organizations such as the Canadian Society for Exercise Physiology (CSEP),^[10] the American College of Sports Medicine (ACSM),^[11] the World Health Organization (WHO),^[12] and the Centers for Disease Control and Prevention (CDC)^[13] produced PA guidelines for people of all ages. These guidelines showed that a higher intensity of PA is related to higher health benefits and recommended at least 60 minutes of daily moderate-to-vigorous intensity PA for children [10, 14]. According to the CDC, moderate activity elicits heart rates between 50-70% of maximum heart rate (HR_{max}), whereas vigorous activity elicits heart rates of 70-85% of HR_{max} . For children and adolescents with disabilities or medical conditions, these guidelines may be suitable; however, they should consult a health professional to determine the types and amounts of PA that fit them [10].

Recently, the International Pediatric Oncology Exercise Guidelines (iPOEG) network agreed on four guidelines and five broad recommendation statements that emphasize the movement's importance for all cancer-affected children and adolescents.³ They recommended further studies to provide specific guidance on exercise safety and the dose, frequency, intensity, time, and type of PA for this population. Thus, this study aimed to examine the applicability

of Nintendo Wii exergames for children with ALL and determine their PA intensity. The significant hypotheses for determining the applicability of exergames were that the games are usable, engaging, and enjoyable; the intensity of PA provided by exergames is consistent with the international PA guidelines.

MATERIALS AND METHODS

Participants

Out of 37 children, a convenience sample of 31 children (17 boys and 14 girls) aged 6-14 years of both sexes diagnosed with ALL¹⁵ and treated with chemotherapy (Vincristine and Methotrexate) was included in this study. Children with hearing or visual impairment, co-morbid conditions, or stem cell transplantation were excluded.¹⁶ The sample size was determined according to Serdar et al., 2021.¹⁷

Design and setting

This preliminary study was conducted in two different hospitals- King Fahad Children's Cancer Center (KFCCC) in King Faisal Specialist Hospital and Research Center (KFSH and RC) and the oncology center in King Fahad Medical City (KFMC), Riyadh, Saudi Arabia (SA). The data were collected between April 2019 and October 2019.

Ethical considerations

Research Ethics Committees approved the study at King Saud University Medical College (E-19-3749), KFSH and RC (RAC number: 2191129), and KFMC (IRB log Number: 19-116E), Riyadh, SA. Parents or guardians provided informed written consent. The trial was registered at clinicaltrials.gov with the ID: NCT04663516.

PROCEDURE

Anthropometric measurements

The demographic data (age, gender, weight by kilogram (kg), height in centimeters (cm), nationality, and chemotherapy information) were collected at baseline. Then, the BMI percentile (BMI%) was calculated using the CDC BMI percentile calculator [13].

Measurement of the applicability of Nintendo Wii exergames

The video games applicability questionnaire was used to test the applicability of exergaming. It consists of 7 statements: two statements concerning usability- (1) "It was easy to learn the game" and (2) "It was easy to use the board and controllers," three concerning engagement- (1) "I didn't want to stop playing," (2) "I lost track of time as I play," and (3) "I can't tell that I am getting tired while playing this game," and two concerning enjoyment- (1) "the games were fun" and (2) "I liked the characters and graphics." Children circled their responses to each question on a five-point pictorial Likert scale with smiles ranking from one- strongly disagree- to five- strongly agree (Figure 1).¹⁸⁻²⁰

The questionnaire was translated and cross-culturally adapted into Arabic following the principles of translating, adapting, and validating instruments for oncology healthcare research (Table 1) [21, 22]. Ten patients piloted the Arabic version to test its face and content validity; the con-

tent validity was tested by the expert committee using the content validity index (CVI) [23]. According to the methodology of Polit et al., 2007, the CVI value of each item on a scale (I-CVI), as well as the overall scale (S-CVI), were determined. Modified Kappa calculated the inter-rater agreement that adjusts for the chance agreement [24]. The Arabic version of the questionnaire was relevant and applicable to children with ALL. The values of I-CVI, S-CVI/UA, and S-CVI/Ave were equal to one. The K^* of each item (>0.74) and the internal consistency of the questionnaire (Cronbach alpha= 0.8) were excellent.

	Applicability measure questions أسئلة قياس قابلية التطبيق	1 Strongly Disagree أرفض بشدة	2 Disagree أرفض	3 Neutral محايد	4 Agree أوافق	5 Strongly Agree أوافق بشدة
Usability قابلية الاستخدام	1/The Wii games are easily usable اللعاب وي سهلة الاستخدام	☹️	😞	😐	🙂	😄
	2/it was easy to use the board and controllers according to the avatar كان استخدام اللوح وأيدي التحكم سهلا مع اللعبة	☹️	😞	😐	🙂	😄
Engagement المشاركة	1/I didn't want to stop playing لم أريد أن أتوقف عن اللعب	☹️	😞	😐	🙂	😄
	2/I lost track of time as I play لم أشعر بالوقت مع اللعب	☹️	😞	😐	🙂	😄
	3/I can't tell that am getting tired while playing the games لم أشعر بالتعب مع اللعب	☹️	😞	😐	🙂	😄
Enjoyment الاستمتاع	1/ The games were fun كانت الألعاب ممتعة	☹️	😞	😐	🙂	😄
	2/I liked the character and graphics أعجبتني الصور والشخصيات	☹️	😞	😐	🙂	😄

Figure 1 Caption: Translated and adapted Arabic version of video game applicability questionnaire with pictorial five Likert scale.

Figure 1 Alt Text: The adapted Arabic questionnaire consists of seven statements appropriate for children. Two related to usability, three related to engagement, and two related to enjoyment. These statements are to be rated on a five-point Likert scale represented by five faces with smiles ranking from one- strongly disagree to five- strongly agree. After the exergaming session, the children completed the questionnaire when their heart rates rested. Afterward, the researcher interviewed each participant to discuss their rating of the applicability of each game.

Measurement of exergaming intensity

Polar, Lake Success, NY HR monitor, and a Portable Beurer pulse Oximeter were used to measure the children's HR and oxygen saturation (SpO_2) at baseline, every 15 minutes, and at the end of the session. The predicted HR_{max} (pred. HR_{max}) was calculated using the formula $208 - 0.7 \times \text{age of a child}$.²⁵ The percentage of increase of HR from the pred. HR_{max} (% pred. HR_{max}) was used to determine each child's level of effort [25]. At the end of the session, all children were asked, "How hard do you feel you are working?" using a valid facial rating of perceived exertion (FRPE) scale, and their responses were recorded (Figure 2) [26].

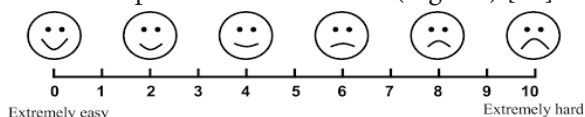


Figure 2 Caption: The Facial Rating of Perceived Exertion (FRPE) scale (Chen et al., 2017).

Figure 2 Alt Text: A set of six faces express different levels of distress. The first face has a wide smile, while the last has a very sad expression. There is a numerical line from 0 to 10 and two phrases; extremely easy at the beginning of the line and extremely hard at the end.

Exergaming procedure

The Nintendo Wii was set up in an empty room where the Wii sensor rested on a table under the screen; two Wii remotes were available, and the Wii balance board (WBB) was fixed on the ground a two-meter distance from the screen.

To give an overall workout of varying intensities, the game session alternated between 7 Wii Sports Resort (Bowling, Swordplay, Table tennis, canoeing, Archery, Basketball, and Frisbee) and 23 Wii fit plus exergames: 4 aerobic (Run, step, rhythmic boxing, and Hula-hoop), 12 training plus (Island cycling, Tilt city, Snowball fight, Skateboard Arena, Rhythm Kung Fu, Rhythm parade, Driving range, Segway circuit, Obstacle Course, Bird's-eye bull's-eye, Big top juggling, and Perfect Ten), and seven balance games (Soccer heading, table tilt plus, balance bubble, Penguin slide, a tightrope walk, Ski slalom, and Ski-Jump) [27, 28]. The children could select and play games for one 60-minute session.

The exergaming protocol followed the Oncology PA guidelines [29, 30]. In addition, all the provided games had the following criteria: using all body parts to control the avatar, the constant movement of at least two body parts to play, and a standing position [18, 31]. Before the session, the supervisor- a senior pediatric physical therapist- demonstrated how to play each game using the Wii remotes or the WBB by the avatar.

The session was conducted on the same day as a chemotherapy dose, just before it was administered or two days later. There was no limit to how many games the child played as long as it was within 60 minutes of session time. Suppose a child had SpO_2 below 92% or HR above the pred. HR_{max} , they are asked to rest until the vital signs are normalized.³²

Statistical analysis

Kolmogorov-Smirnov test was used to check the data's normality. Descriptive statistics summarized the children's demographic and clinical parameters. If skewed, the variables were presented as mean \pm SD and 95% confidence interval for normally distributed data or median (1st and 3rd quartile). Categorical data were expressed as frequency and percentage. Paired-t test compared the HR pre and post-exergaming session. Unpaired-t test compared the intensity of exergaming between boys and girls. Statistical analysis was performed using IBM SPSS statistics for Windows, version 24 (IBM Corp., Armonk, NY., USA)

RESULTS

In total, 37 children were tested for eligibility: 31 were included, and six were excluded because they were unwilling to participate. All data are typically distributed ($P > 0.05$) except age. Children's demographic and clinical character-

istics are presented in Table 1

Table 1: Anthropometric and clinical characteristics of the participants (n=31)

VariableS	Median	Range	
Age	8	6-14	
	Mean	SD	
Height (cm)	130.5	15.9	
Weight (kg)	29.5	10.5	
	Frequency	%	
Gender	Boys	17	54.8
	Girls	14	45.2
BMI%	Underweight (0-5)	6	19.4
	Healthy weight (5-85)	18	58.1
	Overweight (85-95)	5	16.1
	Obese (95-100)	2	6.5
Nationality	Saudi	22	71.0
	Non-Saudi	9	29.0
Diagnosis	Standard Risk ALL	11	35.5
	High Risk ALL	20	64.5
Chemotherapy-phase	Induction	2	6.5
	Consolidation	1	3.2
	Interim-maintenance	8	25.8
	Delayed-intensification	7	22.6
	Maintenance	13	41.9

Data are represented as mean ±SD or frequency and percentage (%) unless otherwise stated. cm: height in centimeters Kg: weight in kilogram, BMI: Body Mass Index. n = number of subjects).

Applicability of Nintendo Wii exergames

Most participants (74.2%) found that exergaming was usable. They strongly agreed with both statements, “It was easy to learn the game” and “It was easy to use the board and controllers according to the avatar.” Regarding engagement, about 83.9% did not want to stop playing and agreed and strongly agreed with the statement “I did not want to stop playing.” Around 80.6 % agreed or strongly agreed with the statement “I lost track of time as they played.” The statement “I cannot tell that I am getting tired while playing” received a neutral rating from most participants (87.1%). Furthermore, almost all participants (93.6%) regarded exergaming to be enjoyable, rating “strongly agree” and “agree” to the statements “The games were fun” and “I liked the graphics and characters,” respectively (Table 2).

Table 2: Applicability of the Nintendo Wii exergames

	SD (1) n (%)	D (2) n (%)	N (3) n (%)	A (4) n (%)	SA (5) n (%)
Usability					
1. It was easy to learn the game	0 (0)	1 (3.2)	7 (22.6)	7 (22.6)	16 (51.6)
2. It was easy to use the board and controllers according to the avatar	0 (0)	1 (3.2)	7 (22.6)	10 (32.3)	13 (41.9)
Engagement					
1. I did not want to stop playing	0 (0)	0 (0)	5 (16.1)	12 (38.7)	14 (45.2)

2. I lost track of time as I play	0 (0)	0 (0)	6 (19.4)	9 (29)	16 (51.6)
3. I cannot tell that am getting tired while playing	0 (0)	2 (6.5)	27 (87.1)	2 (6.5)	0 (0)
Enjoyment					
1. The games were fun	0 (0)	0 (0)	2 (6.5)	11 (35.5)	18 (58.1)
2. I liked the character and graphics	0 (0)	0 (0)	1 (3.2)	9 (29)	21 (67.7)

Data presented as n = number of subjects and (%) = percentage. The rating was on a Likert scale: SD (1) = strongly disagree, D (2) =disagree, N (3) =neutral, A (4) =agree, SA (5) =strongly agree.

Precisely, the participants rated the applicability of each game; only 23 games were applicable. The commonly used nine games were Island cycling (n:29, 93.5%), Bowling (n:25, 80.6%), Swordplay (n:23, 47.2%), Table tennis (n:15, 48.4%), Run (n:12, 38.7%), Tilt city (n:9, 29%), canoeing (n:9, 29%), Archery (n:6, 19.4%), and Basketball (n:6, 19.4%). Most participants found Hula-hoop, table tilt plus, balance bubble, step, rhythmic boxing, and tightrope walk difficult. Ski-Jump was not tested for applicability since none of the participants was interested in using it. Notably, no joint or muscle pain or adverse events were reported. This hinted that exergaming is safe for children with ALL.

The intensity of Nintendo Wii Exergames

The HR significantly increased after the session (P <0.05). The mean of pred. HR_{max} was 201.97 ± 1.72 bpm. The values of % pred. HR_{max} were 50 ± 5.7, 51.4 ± 8.9, 54.7 ± 7.5, and 59.22±8.40 % after 15,30,45, and 60 minutes respectively. Five participants (boys) reached less than 50% of pred. HR_{max} while none of them had a % pred. HR_{max} of more than 70%.

Notably, the ages of boys and girls were matched (mean= 8.24± 2.41 and 9.57± 2.90 years for boys and girls respectively, P= 0.22). At baseline, there was no significant difference in HR between boys and girls (mean = 78.82± 8.64 and 80.21± 12.15 bpm for boys and girls, respectively, P = 0.01). After the 60 min session, girls showed a statistically significant increase in HR (Mean = 116.65± 16.23 bpm for boys and 126.64± 8.21 bpm for girls, P=0.01) and in % pred. HR_{max} (Mean= 56.32± 9.92 for boys and 62.74± 4.15 for girls; P = 0.01) compared to boys. The perceived exertion (PE) level was 5.74± 0.63 at the end of the session. Meanwhile, none of the participants’ SpO₂ levels dropped below 92 % during the session.

DISCUSSION

This study added insight into the applicability of 7 Wii sports resorts and 23 Wii fit plus exergames for children with ALL. It determined the intensity of PA provided by these exergames after a 60-minute session. This study proposed that 23 out of the 30 tested exergames were applicable. The games were usable, engaging, enjoyable, and tolerated by children with ALL. The intensity of exergaming fit the criteria of moderate-intensity PA where the average effort exerted by children was 59.22±8.40 % increase of

pred. HR_{max} .

Children agreed that the games were usable (74.2%), engaging (83.9%), and enjoyable (93.6%). Similarly, other studies implemented Wii exergames on children with various health issues- cerebral palsy (CP), obesity, cystic fibrosis, Down syndrome, and burns- and found that the children were joyful and motivated [8].

When exergaming was applied to children with CP, they found it easier to win at boxing than table tennis.⁶ In this study, however, since peripheral neuropathy and muscle weakness- side effects of chemotherapy- lead to poor coordination, the children found boxing harder because it requires rhythmic movements. Hamari et al.'s 2019 study supported our results: they reported that school-age children with ALL had positive experiences playing the exergames [31].

During the session, children could select their favorite games from various age-appropriate games. This preference was influenced by Hamlyn-Williams, 2014 who found that self-selected exercise intensity has a greater quality and effect than imposed exercise intensity [33] with a possibility of long-term adherence. In addition, when children aged six years underutilized the same activities, they challenged themselves to understand the game and retain their concentration while playing [31].

As Kauhanen (2014) recommended, the children were supervised throughout the session [34]. In addition, no child complained of any adverse events (joint or muscle pain). Meanwhile, the SpO_2 level was normal (94%), consistent with widely reported normal values [35]. Accordingly, consistent with the other research, [36-39] Wii exergames were not only applicable for children with ALL but also safe.

Compared to healthy children, patients with ALL showed severe impairments in motor abilities across different domains of motor functioning [40]. They lack strength and endurance; hence, they could benefit from strengthening and aerobic exercises [41]. According to Stössel et al., 2020, patients with ALL should exercise with moderate intensity [42]. In this study, the intensity of exergaming was measured by the % pred. HR_{max} . More crucially, the pred. HR_{max} , which specifies the upper limit of cardiovascular function, can determine the optimal exercise intensity [43]. It is routinely used as a criterion for assessing maximal effort during graded exercise testing along with other variables such as maximal oxygen uptake (VO_{2max}), maximal carbon dioxide extraction (VCO_{2max}), and maximum ventilation [25, 43].

Our findings provide quantitative evidence of the intensity exerted by exergaming using Nintendo Wii. The average effort exerted by children was 59.22 ± 8.40 % increase of pred. HR_{max} . According to CDC guidelines, the exercise induces a 50–70% increase in pred. HR_{max} is classified as a moderate level of exertion [13, 29].

In agreement with Kauhanen (2014), this study found that the intensity of exergames should be kept within a mode-

rate range [34]. Furthermore, Okada et al., 2012 reported that exercise intensity can begin at ~ 40 % pred for children with cancer on treatment. HR_{max} and work up to 70% or greater if no concerns about immunological problems exist [44]. With typically developed children, similar results were discovered, leading to the conclusion that Wii fit and Wii sports active exergames reach moderate intensity (65-68% of age-predicted HR_{max}) [45].

Interestingly, girls had a significantly higher HR and % pred. HR_{max} after exergaming than boys. According to the literature, girls engage in less physical exercise than boys, possibly due to societal factors or because boys place a greater emphasis on sports than girls [46]. In addition, PA improves heart function, resulting in a lower HR for a given workload, [47] which could explain why boys' HRs were lower than girls' following the same exercise.

Further support besides the HR data comes from the PE scales. The FRPE scale effectively reflects the perceived workload of children and young adults. Whereas the Borg CR10 scale- which uses written words to describe physical workload does not since children did not understand words as effectively as adults; however, the children understood facial expressions [26].

In this study, the level of PE was 5.74 ± 0.63 at the end of the session. A score of 4 or 6 on a 10-point scale would be comparable to moderate-intensity exercise [48]. Since no existing data exists about the intensity of exergaming in children with cancer- to the best of our knowledge, it was difficult to compare our results. The two measures, HR and FRPE, used in this study determined the exercise intensity of the exergames and suggested that playing these games can yield moderate exercise intensity.

Overall, for children with cancer, it is important to meet the international PA guidelines. This may need exercises with smaller and more frequent doses to compensate for the treatment's acute side effects and cancer-related fatigue (CRF).

The findings may provide evidence to facilitate specific guidelines and recommendation statements (intensity, time, and type) for using exercise (Nintendo Wii exergames) in children with cancer. Future studies with larger sample sizes, including other types of cancer, are required. To better generalize the results, other measurements, such as energy expenditure and VO_{2max} could be used to investigate the intensity of exergaming. The intensity of each game was not examined independently: the researchers allowed the children to select and play multiple games to boost motivation, engagement, and enjoyment. Research is needed to determine the impact of exergaming using the guidelines presented in this study (intensity, time, and type of games) on CRF.

CONCLUSION

Nintendo Wii exergames are applicable and safe for children with ALL. When played for 60 minutes under supervision, exergaming enabled the children to achieve PA with moderate intensity. Therefore, they could be utilized clini-

cally as a rehabilitation tool for children with ALL.

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Disclosure statement

The authors report there are no competing interests to declare.

Data availability statement

The data supporting this study's findings are available on request from the corresponding author. However, the data are not publicly available due to their containing information that could compromise the privacy of research participants.

Author contribution statement

All of the listed authors made substantial contributions to this manuscript. Afaf A. M Shaheen contributed to the conception and design of the study, analyzed and interpreted the data, and contributed to the writing process and preparation of the final version of the manuscript. Afnan E. Masoud contributed to the conception and design of the study, collected the data, and participated in the data analysis. Maha F. Algabbani contributed to the conception and design of the study and participated in the writing process and the revision of the manuscript. All authors provided critical feedback, helped shape the research, analysis, and manuscript, and approved the final version.

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