Effects of an online exercise programme on bone health in paediatric cancer survivors: the iBoneFIT study protocol

Background

Currently, one of every 640 young adults is a paediatric cancer survivor. The paediatric cancer incidence has shown an increase of 13%; the 5-year survival rate is now at 80% (1). Unfortunately, the cure has its own consequences and the long-term complications of the disease and its treatment have become crucial. The treatment of paediatric cancer by means of radiation, chemotherapy and/or surgery is associated with various late effects (e.g. impaired growth, musculoskeletal sequelae, cardiopulmonary compromise and secondary malignancy) (1–3), predisposing paediatric cancer survivors to disabling and life-threatening chronic conditions (2). Paediatric cancer treatment has been also documented to have an effect on emotional well-being and quality of life, with survivors reporting anxiety, depression and post-traumatic stress (4,5). Endocrine dysfunction represents one of the most common issues in paediatric cancer survivors. Gonadal failure following exposure to radiation or gonadotoxic chemotherapy and hypothalamic pituitary dysfunction by means of central nervous system radiation can adversely affect bone mineral density (BMD) (6). Moreover, cytotoxic effects on the epiphyseal chondrocytes following direct radiation to bone cause hypervascularity and reduced bone strength (7,8), increasing osteoporosis risk later in life (9).

Paediatric cancer is a life-threatening condition, that also occurs during the period of bone development and strengthening. Our skeleton acquires around 80-90% of its peak bone mass in the third decade of life (10,11). In this regard, adolescents increasing their peak bone mass by 10% might reduce their fracture risk by 50% and delay the onset of osteoporosis by 13 years (12). Thus, although osteoporosis is a disease affecting primarily the elderly, it has its foundation in childhood (13). Observational studies have found low areal BMD (aBMD) during and after cancer treatment to be associated with increased fracture risk (80% increase for every 1 SD reduction in lumbar spine aBMD Z-score) (14–17), which can lead to a higher risk of osteopenia and osteoporosis in adulthood and finally, disability (18,19). Moreover, data from a review showed that up to 68% of paediatric cancer survivors presented moderate-to-severe aBMD deficits (Z-score < -1), while up to 46% had severe aBMD deficits (Z-score < -2) (20). Therefore, there is an urgent need for solutions to improve bone health in paediatric cancer survivors.
High-intensity, weight bearing physical activity is known to improve bone mass (21,22) and is considered an important determinant of the accrual (23) and maintenance (24) of bone mass due to the ability of the skeleton to adapt to the loads under which it is placed. Therefore, and taking into account the Exercise Guidelines for Cancer Survivors (25), conducting an exercise intervention to improve bone mass seems to be a timely and good option.

**Exercise and bone health**

Exercise, as a form of physical activity, is key for developing healthy bones during growing years particularly short bouts of weight-bearing activities, that elicit a variety of strains and include multiple rest periods (26–28). Research has shown that moderate weight-bearing exercise may increase femoral volumetric BMD in prepubertal children, and therefore bone strength (29). Exercise contributes to the development of bone mass in youths due to its association with increases in lean mass as explained by the mechanostat theory (30). Moreover, a recent systematic review has shown that plyometric training causes improvements in bone mineral content (BMC), aBMD and structural properties in children and adolescents (31). More specifically, an 8-month jumping intervention (~3 min/day) improved bone mass in the proximal femur in pubertal children (32). Mackelvie et al. (33) showed that a 7-month jumping intervention (10 min, 3 times/week) enhanced bone mass in the femoral neck and lumbar spine in pubertal girls. Additionally, Vlachopoulos et al. (34,35) found that a 9-month jumping intervention (10 min, 3 to 4 times/week) improved bone outcomes in adolescent males participating in non-osteogenic sports.

A similar effect might be seen in survivors of paediatric cancer. A randomized controlled trial (RCT) in children with acute lymphoblastic leukaemia showed that the exercise programme was unsuccessful in preventing the reduction in aBMD (36). However, the intervention (duration, load) was not properly described. A different RCT focusing on low-magnitude, high frequency mechanical stimulation resulted in increased total body aBMD in paediatric cancer survivors, while a reduction in total body aBMD was observed in the placebo group (37). In a recent study in children with cancer, the exercise programme was not successful in improving aBMD nor other factors such as physical function or health-related quality of life (38). This was because physical activity
requires of certain intensity to modify these factors and this could not be achieved during treatment due to the child's responses to the treatment and disease. Considering the gap in the literature, it is crucial to develop and implement feasible exercise intervention programmes for bone health in paediatric cancer survivors.

Previous studies in this population have shown an increase in body mass index (39) and poor adherence to dietary and physical activity guidelines (40,41). Notwithstanding, the improvement in bone parameters reported in children and adolescents is due to an increase in lean mass and not to greater fat mass (42). With this in mind, there is a need for conducting exercise interventions aiming to improve bone health into survivorship and to educate about the importance of physical activity and dietary quality to ensure that healthy habits are established and maintained throughout life (43).

Study objectives

The aim of the iBoneFIT study is to examine the effect of a 9-month exercise programme on bone outcomes in paediatric cancer survivors and follow up these outcomes 4 months after the intervention.

The secondary objective of the study is to assess the effect of the 9-month exercise programme on body composition, physical fitness, physical activity, quality of life and mental health in paediatric cancer survivors aged 6-18 years.
Methods/Design

Study design

This study protocol is written following the SPIRIT guidelines for clinical trials (44). iBoneFIT is an RCT that will involve a minimum of 102 paediatric cancer survivors aged 6-18 years. For reasons of feasibility, the study will be conducted in 2 waves along two different time periods. Participants will be randomized into an intervention group (IG) and a control group (CG) using the simple randomization. In addition, a follow-up measure will be taken after four months to determine the extent of residual effect. A graphical description of the study design is shown in Figure 1.

![Figure 1. iBoneFIT study design](image-url)
**Sample size**

We have used femoral neck aBMD to calculate the sample size, since it is a key variable in the diagnosis of osteoporosis. Based on an expected effect size of 0.25 for the change in femoral neck aBMD, an α level of 0.05 and a power of 95%, a minimum of 102 participants will be required (IG=51 and CG=51). This includes a 40% extra for occasional losses and refusals and 10% for multivariable analyses. Calculations have been obtained using G*Power (v.3.1.9.2) with ANOVA: repeated measures (within-between interactions) for 2 groups (between factors) and 2 time points (pre, post, within factors). A correlation between measures of 0.7 has been assumed, which is achievable when measuring bone outcomes (18).

**Recruitment**

Eligible participants will be contacted via telephone calls or information letters from the Units of Paediatric Oncology of the ‘Virgen de las Nieves’ (Granada), ‘Reina Sofía’ (Córdoba) and ‘Materno Infantil’ (Málaga) University Hospitals in Southern Spain. A short study information brochure will be used in routine check-ups. A meeting will be held with potential participants and parents/tutors to carefully inform about the benefits and risks of the study, and researchers will answer any question that they may have. Then, informed consents will be given, and participants will have 15 days to send it to the researchers. A hotline will be available to clarify remaining questions about the study. Those who do not react to the study invitation will be followed up via phone call at the end of these 15 days in order to check if they wish to participate. All participants will sign the informed consent before their visit to the Sport and Health University Research Institute (iMUDS, University of Granada).

**Inclusion and exclusion criteria**

iBoneFIT includes paediatric cancer survivors: 1) aged 6 to 18 years old; 2) diagnosed since ≥ 1yr; 3) to have been exposed to radiotherapy or chemotherapy; and 4) not currently receiving treatment for cancer.

Exclusion criteria are defined as follows: 1) simultaneous participation in another study; 2) previous diagnosed anorexia nervosa/bulimia, known pregnancy and/or known
alcohol and drug abuse; 3) children requiring chronic oral glucocorticoid therapy; 4) having an injury that may affect daily life activities and can be aggravated by exercise; and 5) to have a lower limb prosthesis.

**Ethic approval**

This study has been checked and approved by the Ethics Committee on Human Research of Regional Government of Andalusia (Reference: 4500, December 2019) and was submitted to be registered in the [isrctn.com](http://isrctn.com) (Reference: isrctn61195625). Collected data will be protected by pseudonymization and only accessible to the researchers involved in the study. All assessments will be performed by paediatric oncologists and experienced researchers.
Assessments

**Anthropometry**

Body mass (kg) will be measured with an electronic scale (SECA 861, Hamburg, Germany) with an accuracy of 100 g. Height (cm) will be measured by using a precision stadiometer (SECA 225, Hamburg, Germany) to the nearest 0.1 cm. Body mass index (BMI) will be calculated as body mass (kg)/height (m²), and the participants will be classified into BMI categories according to sex- and age-specific cut offs (45). In addition, maturation status will be assessed using the prediction of years from peak height velocity using validated algorithms for children (46).

**Body composition**

*Dual-energy x-ray absorptiometry (DXA)*

A DXA (Hologic Series Discovery QDR, Bedford, MA, USA) will be used throughout the study to obtain BMC (g) and aBMD (g/cm²) for the hip, lumbar spine and total body less head. Furthermore, lean mass (g), fat mass (kg) and body fat percentage (%) for the whole body will be obtained from total body scans. APEX software (version 4.0.2) will be used to analyse the scans following the recommendations for children and adolescents (47). Equipment calibration, participant setting and scan analyses will be performed by the same researcher. DXA uses a minimal radiation (i.e. spending a day outside in the sunshine) and the effective dose for the scans in children has been set in 3-6 μSv (48).

*Hip structural analysis (HSA)*

HSA is a DXA-based software that analyses hip scans to estimate bone geometric properties of the proximal femur. This software analyses structural characteristics through the distribution of bone mineral mass in a line of pixels across the bone axis (49). These geometric estimates in the proximal femur will be derived from: 1) the cross-sectional area (mm²); 2) section modulus (mm³); and 3) the cross-sectional moment of inertia (mm⁴). For these variables, the short-term coefficient of variation has been reported to be between 2.4% and 10.1% (50).
Trabecular bone score (TBS)

TBS is a DXA-based software (iNsight version 3.0, Medimaps, Pessac, France) that indirectly assesses the state of trabecular microarchitecture in the lumbar spine. Based on experimental variograms of the projected DXA image, TBS evaluates the heterogeneity of the grey-levels pixels of the aBMD and higher heterogeneity implies worse trabecular connectivity (51). Low values reported in this parameter have been associated with a higher fracture risk, and therefore it is considered an index of bone quality (52). The short-term coefficient of variation for TBS has been reported to be 2.1% and 1.7% for spine aBMD in 92 individuals with repeated spine DXA scans performed within 28 days (53).

3D-DXA Modelling

3D-SHAPER is a DXA-base software (version 2.2, Galgo Medical, Barcelona, Spain) that derives 3D analyses from the hip DXA scans. Details of the model algorithm are published elsewhere (54). Briefly, this software uses a 3D statistical shape and density of the proximal femur built from a database of QCT scans of Caucasian population (54). The 3D model is registered onto the DXA scan to obtain a 3D participant-specific model of the proximal femur. The 3D-SHAPER will assess bone parameters such as the cortex, the femoral shape and the trabecular macrostructure (55).

The cortex is segmented by fitting a mathematical function of the cortical thickness (mm), cortical volumetric BMD (cortical vBMD, mg/cm³), the location of the cortex, the density of surrounding tissues and the imaging blur to the density profile computed along the normal vector at each node of the proximal femur surface mesh (55). In addition, the cortical surface BMD (cortical sBMD, mg/cm²) is computed at each vertex of the femoral surface mesh, as the multiplication of the cortical thickness (cm) by the cortical volumetric BMD (mg/cm³) along its thickness (56). Any increase in either cortical thickness or cortical vBMD will ensure an increase in cortical sBMD. Nevertheless, if cortical thickness and cortical vBMD vary in opposite ways, cortical sBMD will remain unchanged. All measurements will be computed over the total femur (i.e. the shaft, the intertrochanteric and the union of the neck) according to the trabecular, cortical and integral compartments.
Correlation coefficients between BMD computed by 3D-SHAPER and QCT of the total femur have been reported to be 0.86-0.95, whereas the correlation coefficients of BMD computed by 3D-SHAPER with BMD computed by QCT have been reported to be 0.91 (54). The short-term coefficients of variations of aBMD measurements have been reported to be 1.5%, 4.5%, 1.7% and 1.5% for cortical thickness, trabecular vBMD, cortical vBMD and cortical sBMD, respectively (56).

**Bioelectrical impedance analysis (BIA)**

A bioimpedance scale (Tanita BC-418 MA; Amsterdam, The Netherlands; range: 2-200 kg; precision: 0.1 kg; body fat percentage increments: 0.1%) will estimate the percentage of body fat of the participants. The assessment will be carried out in fasting state according to the manufacturer’s instructions. Despite the measured error, BIA will be used to assess body fat as it is considered a practical method in addition to DXA (57).

**Blood samples**

Fasting blood samples will be collected by venepuncture between 8:00 and 10:00 after an overnight fast. The methodology for shipment, preparation and collection of the blood samples was standardized among all participating hospitals. A set of parameters obtained from hematological and biochemical analyses will be available from the hospitals as part of the routine measures.

**Physical fitness assessment**

The ALPHA fitness test battery will be used to assess physical fitness. These field-based fitness tests have been shown to be valid, reliable and related to health in children and adolescents (58). In brief, cardiorespiratory fitness will be assessed with the 20 m shuttle run test; muscular fitness will be assessed with the handgrip strength and standing long jump tests; and speed agility will be assessed with the 4 × 10 m shuttle run test. All tests will be performed twice, and the best score will be retained, except 20 m shuttle run test.
Perceived physical fitness will be assessed by the International Fitness Scale (IFIS). The IFIS is a short, simple and self-administered scale that has been validated in children and adolescents (59,60). In a nutshell, this 5-item scale asks the participants about their physical fitness comparing with their colleagues.

**Physical activity assessment**

Physical activity and sedentary behaviours will be objectively assessed at the baseline, post-intervention and follow-up measurements. Participants will wear a tri-axial accelerometer (ActiGraph GT3X, Pensacola, FL, USA) attached to the non-dominant wrist over seven consecutive days (24 h/day) and they will remove it only for water-based activities (e.g. bathing or swimming). They will also have a diary in order to record the time when they go to bed, wake up and remove the device.

In addition, information on self-reported physical activity and sedentary behaviours will be obtained by the cross-translated and adapted version of the Youth Activity Profile (YAP) questionnaire (available at: [http://profith.ugr.es/yap?lang=en](http://profith.ugr.es/yap?lang=en)). The YAP questionnaire was developed at the Iowa State University and validated in children (61). This self-administered 7-day recall questionnaire collects data from items regarding physical activity in the school setting, physical activity out of the school setting, activity immediately after school, activity during the evening and activity during each weekend day. Moreover, the bone-specific physical activity questionnaire (BPAQ) will be used to assess the influence of historical physical activity (i.e. activities in which you have ever participated, and activities practiced in the last 12 months) on skeletal health. It has been reported that BPAQ is a valid instrument to account for the effects of previous physical activities on the skeleton (62).

**Calcium intake and vitamin D**

To correctly interpret bone health of the participants, an assessment of dietary intake of calcium will be completed at the baseline, post-intervention and follow-up measurements. A validated food-frequency questionnaire will be used to estimate calcium intake (63) and a Vitamin D Questionnaire to assess the status of this prohormone (64).
**Quality of life and well-being**

The Paediatric Quality of Life Inventory (PedsQL™ 4.0 Generic Core Scales) will be used to assess quality of life. PedsQL™ is validated in paediatric cancer survivors and has been successfully used (65). This 23-item scale assesses quality of life considering five domains of health (i.e. physical functioning, emotional functioning, psychosocial functioning, social functioning and school functioning). Results from our participants in all domains of PedsQL™ will be compared to published normative data (66).

Childhood anxiety will be assessed with the State-Trait Anxiety Inventory for Children (STAIC-T). This inventory has been extensively validated in Spanish children (67). Depression will be measured with the Children Depression Inventory (CDI), which consists of 27 items that assesses 5 domains (interpersonal problems, ineffectiveness, negative mood, anhedonia and negative self-esteem) (68). Rosenberg Self-Esteem scale will be used to assess self-esteem and has been validated with children and adolescents (69). We will use the Positive Affect Schedule for children (PANAS-C) in order to measure both positive and negative affect (70). The original PANAS-C reported appropriate values of internal consistency (0.86 for the positive affect and 0.82 for the negative affect). Happiness will be assessed by the Subjective Happiness Scale (SHS) whose Spanish version has shown appropriate test-retest reliability, internal consistency and convergent validity (71). Dispositional optimism will be assessed with the Life Orientation Test-Revised (LOT-R) (72). LOT-R is an instrument with good internal consistency (0.71 for the total score and of 0.64 and 0.77 for the optimism and pessimism, respectively) (73).

**Exercise programme**

The 9-month exercise programme (10-20 min/day) will consist of three stages with progressive increase in load and impact. Each stage will be composed of progressive levels of volume (i.e. repetitions, sets per day and sessions per week). Warm ups will be based on RAMP methodology (i.e. raise, activate, mobilize and potentiate) in order to maximize middle-term performance of the main exercises (74). A different warm up will be provided every two weeks and it will be focused on the brace, squat, lunge or jump patterns. The exercise programme will be performed on a hard surface (75), and participants will be asked to report any pain or injuries at each stage of the intervention.
Table 1 shows the progression of the exercise programme. In stage 1 (8 weeks, 2 levels) participants will perform body mass-based squats and the volume will increase progressively by modifying the number of repetitions and sets per day. In stage 2 (12 weeks, 3 levels) participants will perform squat jumps and the volume will increase progressively by modifying the number of repetitions, sets per day and sessions per week. In stage 3 (16 weeks, 4 levels), participants will perform countermovement jumps and the volume of stage 3 will be increased progressively by modifying the number of repetitions, sets per day and sessions per week. Body mass-based squat was chosen in stage 1 following previous studies that observed positive effects on muscular fitness after an 8-week intervention (76,77). Squat jump was chosen in stage 2 as intermediary exercise before the use of countermovement jump since the jump height reached is lower and hence, ground reaction forces produced at the landing are lower (78). Furthermore, squat jump training reduces the degree of muscle slack on the push-off phase (79) which could supply a better execution of the countermovement jump afterwards. In this regard, countermovement jump was chosen in stage 3 of the intervention since it produces a huge force application (493 times body mass / second) and ground reaction forces (5 times body mass) in prepubertal children (80). Countermovement jump has been previously reported to be valid and reliable in children (81).

Exercise programme and behaviour change techniques

This intervention will be delivered online by making use of social media. Following Edwards et al. (82), five behaviour change techniques (i.e. action planning and goal setting, providing instructions and demonstrations of how to perform the behaviour, self-monitoring of behaviour and providing feedback on performance and information about health consequences) and a gamification design (i.e. points and rankings) will be included to improve the interest and incentive of this non-game programme. These motivational approaches were chosen because of their known effect on physical fitness (83), physical activity (84) and satisfaction (85). Moreover, parents will be told to encourage their children to perform the exercise programme in order to increase motivation.
Compliance

Compliance with the exercise programme will be monitored by checking attendance to sessions. Parents will fill a diary each time the participant performs a session in order to record the number of sessions completed. This will allow us to check adherence to the programme. Acceptable adherence will be defined as completing 80% or more of the total exercise sessions. If a participant has not completed 80% of the exercise programme by the end of the 9 months but can reach 80% within two additional weeks, the programme will be extended for them.

Dietary and physical activity counselling

Participants in both groups will receive information on the recommendations of calcium and vitamin D (86). Educational leaflets and infographics about the importance of physical activity, diet (i.e. calcium and vitamin D) and sun exposure will be delivered at the beginning of each stage. Previous evidence has found vitamin D deficiency in children with cancer at diagnosis, during therapy and also after therapy (46), which can be due to inappropriate nutrition, malabsorption or lack of sun exposure. In this regard, ensuring that participants have adequate vitamin D and calcium levels is important as both interact with physical activity to enhance bone mass (47,48).

Control group

Participants in the CG will be asked to keep its activity level as usual over the entire study period. After the end of the study, participants in the CG will have the opportunity to receive the same online exercise programme and counselling about the importance of physical activity, diet and sun exposure.

Discussion

iBoneFIT will examine the effect of an online RCT exercise programme on bone development in paediatric cancer survivors aged 6-18 years old. In addition, it will follow
up the participants 4 months after the intervention to examine whether the effects remain. Finally, the iBoneFIT will investigate whether the exercise programme can affect body composition, physical fitness, physical activity, quality of life and mental health of paediatric cancer survivors. Several studies highlight that exercise interventions delivered during cancer treatment are not successful in improving bone health nor other factors such as health-related quality of life (36,38), suggesting a new approach focusing on post treatment phase is needed.

Previous evidence shows a higher risk of delayed bone development, diminished muscle functioning, disability and compromised fundamental movement skill acquisition in children who have completed cancer treatment (79). These side effects can also reduce motivation to be physically active and aggravate chronic health conditions in the short and long terms (87). Resistance exercise, jumping or combinations of both have shown improvements in muscular fitness and bone health (34,35,88). In this regard, Guadalupe-Grau et al. (88) found improvements in physical fitness (4-5%), total body BMC (0.78%) and LS BMC (1.2-2%) following a 9-week resistance and plyometric training in adults, whereas Vlachopoulos et al. (35) reported an increase in physical fitness (3.7-7.9%) and BMC at TBLH and legs (4.2-12.7%) in non-osteogenic sports. Moreover, Vlachopoulos et al. (34) showed that a 9-month plyometric training improved LS BMC (4.6%) and femoral neck BMC (6-9.8%) in non-osteogenic sports. Exercise Guidelines for Cancer Survivors recommend avoiding movements that place excessively high load on fragile skeletal sites (25). Thus, our intervention aims to improve muscular strength before implementing mechanical loading through jumping exercises. Mackelvie et al. (89) have suggested that jump training is associated with increases in femoral neck, lumbar spine and total body aBMD (~2%) in prepubertal boys and may delay the onset of osteoporosis later in life. Therefore, it is crucial to analyse the effect of this exercise programme in paediatric cancer survivors.

Furthermore, following the study of McKay et al. (32), the exercise programme should be effective, possible to perform at any place, short in duration, inexpensive and simple to administer. iBoneFIT has been designed to meet all these requirements. The exercise programme will be delivered online and using social media. Some international physical activity interventions based on online and app-based approaches have shown promising results, indicating the suitability of this technology to influence health behaviours (90,91).
iBoneFIT represents a golden opportunity to analyse for the first time the effect of a simple, feasible, inexpensive and short duration exercise programme on bone health in paediatric cancer survivors. This study will target this population in high risk of low BMD, using an enjoyable intervention and cutting-edge technologies (i.e. DXA and tri-axial accelerometers) to assess its effectiveness. If successful, this 9-month online exercise program will likely encourage paediatric cancer survivors to be physically active or even engage in a sport, providing an opportunity to decrease chronic health conditions in the short and long terms (3). Finally, iBoneFIT will substantially contribute to the existing knowledge of how physical activity affects quality of life and well-being in this population. The long-term medical and psychological effects of childhood cancer or its treatment may negatively affect social functioning such as school attendance, obtaining employment and even social activities (87). Therefore, their quality of life and well-being are important concerns, and efforts have to be made to improve it, which will have an important societal and economic impact.
Abbreviations

BMD bone mineral density; BMC bone mineral content; aBMD areal bone mineral density; DXA dual-energy x-ray absorptiometry; TBS trabecular bone score; BIA bioimpedance analysis; IFIS international fitness scale; 25(OH)D 25-hydroxyvitamin D; YAP-S youth activity profile-Spain; BPAQ bone-specific physical activity questionnaire; CDSI children’s daily stress inventory; STAIC-T state-trait anxiety inventory for children; CDI children depression inventory; PANAS-C positive affect schedule for children; SHS subjective happiness scale; LOT-R life orientation test-revised.

Competing interests

The authors declare that they have no competing interests

Authors’ contribution

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<th>Warm up</th>
<th>Exercise</th>
<th>Level</th>
<th>Repetitions</th>
<th>Sets per day</th>
<th>Sessions per Week</th>
<th>Squats/Jumps per Week</th>
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BM body mass; SJ squat jump; CMJ countermovement jump

a Warm up will be focused on dynamic movements with progressive intensity enhancing optimal core body temperature, motor unit excitability, kinesthetic awareness and ranges of motion

b Each BM-based squat will be performed at a pace of once every 2 seconds
Each SJ and CMJ will be performed at a pace of once every 5 seconds

c Rest between sets = 1 min

d In stage 1, all sets will be suggested to perform after school as an after-school activity
In stages 2 and 3, jumps will be suggested to perform in the morning before going to school (1 set), after school (1 set) and before going to bed (1 set). When doing 4 sets per day, jumps will be performed in the morning before going to school (1 set), after school (2 sets) and before going to bed (1 set).
Table 2. Translation and operationalization of BCTs targeting behaviour determinants into BIT elements

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<th>Determinant</th>
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<th>Operationalization</th>
<th>BIT element</th>
<th>Workflow</th>
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<tr>
<td>Perceived behavioural control; Autonomy; Planning; knowledge/awareness</td>
<td>Action planning and goal setting (behaviour)</td>
<td>Inform the participants about the stage of the intervention and goals</td>
<td>WhatsApp group message</td>
<td>Every two weeks (Sunday)</td>
</tr>
<tr>
<td>Perceived behavioural control; Intentions; Competence; Knowledge/awareness</td>
<td>Provide instructions and demonstrations on how to perform the behaviour</td>
<td>Give instructions and demonstrations about how to perform the training session</td>
<td>Videos with exercise proposals</td>
<td>Every two weeks (Sunday)</td>
</tr>
<tr>
<td>Perceived behavioural control; Autonomy; Competence; Knowledge/awareness</td>
<td>Prompt self-monitoring of behaviour</td>
<td>Ask the participants to report the intervention compliance</td>
<td>WhatsApp group message</td>
<td>Immediately after the participants had carried out a session</td>
</tr>
<tr>
<td>Perceived behavioural control; Relatedness; Competence; Knowledge/awareness</td>
<td>Provide feedback on performance</td>
<td>Inform the participants about the discrepancies found between behavioural goals and review of behavioural goals achieved</td>
<td>Send rankings on WhatsApp group</td>
<td>Every two weeks (Saturday) based on the previous achievements</td>
</tr>
<tr>
<td>Perceived behavioural control; Attitude (beliefs); Knowledge/awareness</td>
<td>Information about health consequences</td>
<td>Present press releases to emphasize the importance of physical activity, diet and sun exposure for bone health</td>
<td>WhatsApp group message</td>
<td>At the beginning of each stage (Sunday)</td>
</tr>
</tbody>
</table>

*BCT* behaviour change technique; *BIT* behaviour intervention technology