©Journal of Sports Science and Medicine (2015) **14,** 562-567
http://www.jssm.org

Research article

Characterisation of the Mechanical Loads and Metabolic Intensity of the CAPO Kids Exercise Intervention for Healthy Primary School Children

Rossana C. Nogueira [1,2], Benjamin K. Weeks [1,2] and Belinda R. Beck, [1,2]✉
[1] Centre for Musculoskeletal Research, Menzies Health Institute Queensland, Gold Coast, Queensland, Australia
[2] School of Allied Health Sciences, Griffith University, Gold Coast, Queensland, Australia

Abstract
Sedentarism is associated with obesity and other chronic diseases at all ages. Increasing physical activity with in-school interventions, focusing on energy expenditure and bone loading reduces risk of a number of costly chronic diseases. The aim of the current study was to characterise the metabolic and musculoskeletal load intensity of the recent successful CAPO Kids exercise intervention. Pre and early pubertal children (10.4 ± 0.5 years old) from the CAPO Kids trial wore an armband sensor to estimate energy expenditure during a 10-minute CAPO Kids session. Eleven participants performed manoeuvres from the session on a force platform to determine vertical ground reaction forces. In total, 28 boys and 20 girls had armband measures and 11 boys and girls undertook GRF testing. The energy expenditure associated with the 10-minute session was 39.7 ± 9.3 kcal, with an average of 4 kcal·min^{-1}. The intensity of physical activity was 'vigorous' to 'very vigorous' for 34% of the session. Vertical ground reaction forces of the CAPO Kids manoeuvres ranged from 1.3 ± 0.2 BW (cartwheels) to 5.4 ± 2.3 BW (360° jump). CAPO Kids generates adequate load intensity to stimulate positive health adaptations in both metabolic and musculoskeletal systems of pre and early pubertal children.

Key words: Pediatrics; energy expenditure, ground reaction forces, physical activity.

Introduction

Despite our increasing knowledge of the positive impact of physical activity during childhood for long term health, children are becoming less active (Boreham and Riddoch, 2001; Tremblay et al., 2011a). Childhood sedentary behaviour is strongly associated with obesity (Must and Tybor, 2005; Pearson and Biddle, 2011) and is also known to predict overweight in adolescence and adulthood (Guo et al., 2002; Magarey et al., 2003). In addition, sedentary behaviour is related to other chronic metabolic diseases, such as osteoporosis, type 2 diabetes and ischaemic heart disease (Dunstan et al., 2010; Katzmarzyk et al., 2009; Tremblay et al., 2011a). Increasing physical activity participation in school is notionally a very practical method to improve the health of children at the population level (Boreham and Riddoch, 2001). An exercise regime that would effectively improve the health of multiple body systems, however, is yet to be described. For instance, it is well known that increasing the duration of physical activity is an effective strategy to enhance cardiovascular function (Haskell et al., 2007), but not the skeletal system. To stimulate the latter system, short duration, high intensity loading is required (Lanyon and Rubin, 1984).

Exercise prescriptions can be manipulated in terms of frequency (exercise bouts per week), intensity (metabolic and musculoskeletal load), duration (length of exercise bout), and exercise type (Must and Tybor, 2005). The current physical activity recommendation for children includes the accumulation of 60 minutes per day of moderate to vigorous exercise in addition to activities that strengthen bone and muscle on at least three days per week (Janssen, 2007; Strong et al., 2005; Tremblay et al., 2011b; Twisk, 2001). Measures of intensity traditionally focus on cardiovascular or metabolic load and are classified in terms of heart rate and estimates of energy expenditure (EE) (Haskell et al., 2007). Such measures, however, fail to capture characteristics of mechanical intensity that are vital to the musculoskeletal response. In order to identify childhood activities that are broadly beneficial to multiple systems, it is important to know the intensity of both cardiovascular/metabolic load *and* musculoskeletal load. Furthermore, from a psychosocial standpoint, variety and enjoyment are critically important elements of an exercise program that contribute to uptake and ongoing engagement (Richard et al., 1997).

Accelerometry is a recognised technique to track physical activity in bone and metabolic research (Janz et al., 2003). Accelerometry-derived weight-bearing movements can predict bone mass and density in young children (Janz et al., 2001; Specker et al., 2001). Biomechanical characteristics of weight-bearing exercises are typically estimated by measuring ground reaction forces (GRF) (Prapavessis and McNair, 1999).

The CAPO Kids program was a recent brief and enjoyable in-school exercise intervention designed to improve the musculoskeletal and metabolic health of pre and peripubertal children (Nogueira et al., 2014; 2015). The goal of the program was to simultaneously apply a moderate to vigorous aerobic load and high intensity impact loading. Exercises were based on *capoeira*, a Brazilian sport that combines martial art, dance and music, presenting a new and interesting activity for the participants. *Capoeira* was supplemented with high impact activities including a variety of jumps and upper limb loading activities. The program improved bone health and metabolic factors such as waist circumference, resting heart rate and maximal oxygen uptake over a nine-month period (Nogueira et al., 2014; 2015).

The aim of the present study was to characterise the biomechanical and metabolic loads of the CAPO Kids

Received: 03 December 2014 / Accepted: 14 May 2015 / Published (online): 11 August 2015

exercise program, in boys and girls. Those data will allow others to make an informed judgement with regards to the potential of the program to produce metabolic and musculoskeletal benefit or other outcomes.

Methods

Study design and ethical approval

We conducted a cross-sectional descriptive study of metabolic and mechanical loads experienced by participants in the CAPO Kids trial. Ethical approval was obtained from the Griffith University Human Research Ethics Committee (PES/35/12/HREC), and all participants provided informed consent. Parents had the option to override and decline to consent.

Participants

A sample of the Year 5 and 6 primary school children (9.7-11.4 years of age) who were participating in the 9-month CAPO Kids exercise intervention were recruited for the current study. Participants were included if they were healthy, ambulant, and enrolled in the exercise arm of the trial. Participants were excluded if they had a metabolic, endocrine or renal condition; were taking medications known to affect bone, muscle or fat metabolism; were recovering from a serious lower limb fracture or other immobilising injury in the past six months; or were affected by any condition not compatible with short bouts of physical activity. Specific details of school and participant recruitment are available in previous publications (Nogueira et al., 2014; 2015).

Participants were invited to wear a SenseWear Armband (SWA, BodyMedia, Pittsburgh, PA, USA) for the entirety of one CAPO Kids exercise bout in order to have parameters of metabolic intensity measured. The same participants were also invited to attend a single session of testing at the Biomechanics Laboratory at Griffith University in order to have the ground reaction forces (GRF) associated with intervention activities measured on a force platform. Participation in the GRF session was optional. An *a priori* sample size estimate was not conducted.

Data collection

Anthropometrics: Anthropometric measures included standing and sitting height (portable stadiometer, HART Sport and Leisure, Australia and a 50 cm stool), and body weight (digital scale, Charder MS 3200, CE, Taichung City, Taiwan). Weight was measured in duplicate, while standing and sitting height were determined by a single measure. Body mass index (BMI) was determined from weight and height per the accepted method (BMI = weight·height-2, kg·m-2).

Maturity: Maturity was assessed by calculating years to age of peak height velocity (YAPHV), based on an algorithm that includes several anthropometric variables (Mirwald et al., 2002). The algorithm uses the following variables: date of birth, sex, weight, sitting and standing height; and predicts maturity offset as the number of years the participant is from their estimated age of peak height velocity (APHV). YAPHV is calculated by subtracting APHV from chronological age.

Measurement of metabolic load: Total energy expenditure (EE) was estimated by the SenseWear Pro Armband monitor (SWA version 7.0; BodyMedia, Pittsburgh, PA, USA), using child-specific algorithms (Calabró et al., 2009). The SWA is a wireless, non-invasive multiple-sensor device that collects data derived from skin temperature, galvanic skin response (electrical conductivity of skin) and heat flux when placed on the left arm (on the triceps brachii, mid-way between shoulder and elbow) (St-Onge et al., 2007). The tri-axial inbuilt accelerometers record motion and the total number of steps in an exercise bout. Measures of energy expenditure are calculated using manufacturer software which incorporates user inputted weight, height, sex and age. Physical activity EE is presented in calories (kcal) and in metabolic equivalents (MET), to characterise the 'metabolic intensity' of a bout of exercise. The device has been validated for measures of EE in resting and exercise conditions, for adults (Fruin and Rankin, 2004; Jakicic et al., 2004) and children (Arvidsson et al., 2007; Calabró et al., 2009). Participants wore the SWA while resting for ten minutes before each trial, according to manufacturer recommendations. The participant then wore the SWA for a full 10-minute CAPO Kids session (exercises as described in Table 1). Data collection was held during typical CAPO Kids classes.

Data from the SWA were downloaded onto a personal computer and processed using SenseWear software version 7.0. The data includes minute-by-minute values for EE (kcal), intensity (METs) and number of steps according to in-built algorithms (Calabró et al., 2009). Moderate (3.0 to 5.9 METs), vigorous (6.0 to 8.9 METs), and very vigorous activity (> 9.0 METs) (Nader et al., 2008) was categorised by the software, based on a proprietary equation that has been validated to estimate EE in children (Calabró et al., 2009).

Ground reaction force measures: Vertical ground reaction force (vGRF) parameters were measured for 11 of the most common jumps and capoeira manoeuvres included in the CAPO Kids intervention trial (Table 1). Vertical GRF, including magnitude of and rate of force application were collected at 1 kHz using two 900 mm x 600 mm strain gauge bridge force platforms (Advanced Mechanical Technology, Inc, MA, USA). Vertical GRF data collection was performed in the laboratory, where the force platforms are located. As all were participants of the CAPO Kids trial at the time and had completed five months of the intervention, they were familiar with and competent in all measured activities. A single investigator (RN) demonstrated each activity prior to participant performance. Participants were instructed to perform each activity barefoot, to simulate the typical CAPO Kids session. Activities were performed in the same order for all participants. After several practice attempts, three consecutive attempts of each activity were executed on the force platform.

GRFs were normalised to bodyweight (BW) and the average peak vGRFs (BW) and rates of force application (BW/s) were calculated for each activity from three successful trials using custom-designed software in Matlab 7.8.0 (The MathWorks, Natick, MA).

Table 1. **Descriptions of CAPO kids exercise activities.**

Activity	Description
Hops	Single-leg take off, followed by a single-leg landing on the same side
Hops plus martelo	Single-leg take off, followed by a single-leg landing on the same side, performing a push kick with hanging foot, with the ankle extended (martelo), and returning to the ginga position
Tuck-jumps	Double-leg jump, with hips and knees flexed during flight, bringing the knees into close proximity to the chest, and arms momentarily holding the knees when they reach the chest
360-jumps	Double-leg jump, whereby the body is rotated 360 degrees to either the left or right before landing
Star jumps	With feet together, jumping and positioning legs apart, at the same time the arms go up touching the hands above the head, and returning to the initial position, repetitively
Jump-Lunges	Taking a large step forward so that the knee is flexed to 90 degrees as a start position, jumping while swapping legs, returning to start position with the opposite leg
Ginga	Feet positioned shoulder-width apart, and then one foot is placed behind on the ball of the foot (ginga position). The back foot returns to the initial position, and the other is placed back, imagining that a triangle is being drawn on the floor with the feet – the whole movement is called ginga
Handstands	From ginga position, the hands are placed on the ground shoulder-width apart and the legs kick up, together, open or with one leg forwards
Cartwheels	Traditional movement, but performed slowly and with arms and legs slightly flexed
Jump plus martelo	Starts from the ginga position. After a jump on the ginga position, a push kick is performed with the back foot, with the ankle extended before returning to the ginga position (martelo).
Running	Running fast on the spot

Statistical analysis

Statistical analyses were performed with SPSS version 22.0 for Windows (IBM, Chicago, IL). Descriptive statistics were calculated, including means and standard deviations for participant characteristics and means, standard deviations and 95% confidence intervals for all dependent variables derived from SWA and GRF collection. Independent *t* tests were used to examine sex differences for metabolic data. Statistical significance was determined to be ≤ 0.05.

Results

Participant characteristics

A total of 48 children (28 boys; 20 girls) participated in the study, representing approximately 15% of the CAPO Kids group cohort. All participants completed SWA data collection, while a subsample of 11 children (6 boys; 5 girls) completed GRF data collection. Descriptive characteristics are provided in Table 2. Age, weight, standing height, BMI and estimated VO_2 max were similar between boys and girls included in the study (Table 2).

Metabolic measures

Results for metabolic measures including EE (kcal and METs), number of steps and intensity of PA for combined and sex-specific samples are presented in Table 3. The average duration of the CAPO Kids activity was 10.2 ± 0.6 minutes. Both boys and girls had similar EE (38.7 ± 7.3 vs. 41.2 ± 11.8 kcal, p = 0.371), METs (5.5 ± 0.9 vs. 5.6 ± 0.9 METs, p = 0.641); total steps (690 ± 92 vs. 636 ± 97, p = 0.056) and duration in each PA intensity zone. The average EE was 4.0 $kcal \cdot min^{-1}$ for both groups, which is classified as moderate intensity. Moderate PA intensity lasted an average of 6.9 ± 2.3 min for boys vs. 6.5 ± 2.9 min for girls (p = 0.602); vigorous intensity lasted 3.0 ± 0.8 min for boys vs. 2.6 ± 1.7 min for girls (p = 0.431); and very vigorous intensity lasted 0.5 ± 0.9 min vs. 0.7 ± 0.8 min (p = 0.510) for boys and girls respectively.

Table 2. **Participant characteristics (n = 48). Data are means (±SD).**

Characteristic	Whole Group	Boys (n = 28)	Girls (n = 20)
Age (years)	10.4 (.5)	10.4 (.5)	10.4 (.5)
YAPHV (years)	-2.32 (.94)	-3.03 (.44)	-1.39 (.52) ***
Weight (kg)	36.3 (7.6)	35.8 (6.9)	37.1 (8.7)
Standing height (m)	1.43 (.06)	1.43 (.06)	1.43 (.07)
Body mass index ($kg \cdot m^{-2}$)	17.8 (3.1)	17.5 (2.8)	18.1 (3.6)
Estimated VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$)	27.5 (7.0)	28.9 (7.8)	25.5 (5.1)

VO_2 max, maximal oxygen consumption; YAPHV, years from age of peak height velocity. *** p < 0.001

Table 3. **Metabolic data for a single 10-minute CAPO Kids exercise bout (n = 48).**

Characteristic	Whole Group	95% CI	Boys (n = 28)	95% CI	Girls (n = 20)	95% CI
PA duration (min)	10.2 ± 0.6	10.0 - 10.4	10.3 ± 0.6	10.1 - 10.5	10.2 ± 0.7	9.8 - 10.5
EE / session (kcal)	39.7 ± 9.3	37.0 - 42.5	38.7 ± 7.3	36.2 - 41.8	41.2 ± 11.8	35.8 - 46.8
Average METs	5.5 ± 0.9	5.3 - 5.8	5.5 ± 0.9	5.1 - 5.8	5.6 ± 0.9	5.2 - 6.0
Total steps	668 ± 98	640 – 696	690 ± 92	655 – 726	636 ± 97	591 – 682
Moderate PA (min)	6.7 ± 2.5	6.0 -7.5	6.9 ± 2.3	6.0 - 7.8	6.5 ± 2.9	5.2 - 7.8
Vigorous PA (min)	2.8 ± 1.8	2.3 - 3.3	3.0 ±0.8	2.3 - 3.7	2.6 ± 1.7	1.8 - 3.3
Very vigorous PA (min)	0.6 ± 0.9	0.3 - 0.8	0.5 ± 0.9	0.2 - 0.8	0.7 ± 0.8	0.3 - 1.0

PA, Physical activity; EE, Energy expenditure; MET, metabolic equivalent; Min, minutes.

Table 4. **Vertical ground reaction forces and rates of force application for each CAPO Kids exercise (n = 11). Data are means (±SD).**

Activity	vGRF (BW)	95% CI	Rate of Application (BW·s^{-1})	95% CI
360 jump	5.4 (2.3)	3.9 - 6.9	132.4 (78.6)	79.6 - 185.2
Cartwheel	1.3 (.2)	1.1 - 1.4	15.0 (18.7)	2.4 - 27.5
Ginga	1.4 (.4)	1.1 - 1.7	15.0 (17.3)	2.6 - 27.4
Handstand	1.4 (.2)	1.2 - 1.5	26.5 (17.5)	14.7 - 38.2
Hop	4.0 (1.0)	3.3 - 4.7	54.0 (13.7)	44.3 - 63.8
Hop plus martelo	4.0 (1.2)	3.3 - 4.7	92.4 (74.7)	39.0 - 145.8
Jump-lunges	1.5 (.6)	1.1 - 1.9	143.6 (144.9)	46.3 - 241.0
Jump plus martelo	4.8 (1.2)	3.9 - 5.7	121.8 (93.5)	54.8 - 188.7
Star jumps	2.9 (.7)	2.4 - 3.3	51.8 (24.6)	34.2 - 69.4
Running	2.7 (.5)	2.4 - 3.0	27.5 (8.7)	21.7 - 33.4
Tuck jump	5.2 (2.0)	3.8 v 6.6	106.5 (37.9)	81.0 - 132.0

vGRF, vertical ground reaction forces; BW, body weight.

Mechanical measures

Table 4 presents GRF measures including the average of vGRF magnitude and rates of application for each activity performed during the CAPO Kids intervention. The 360° jumps and tuck jumps produced the highest vGRFs (5.4 ± 2.3 and 5.2 ± 2.0 BW, respectively), followed by jump plus martelo (4.8 ± 1.2 BW), and then hop and hop plus martelo (4.0 ± 1.0 and 4.0 ± 1.2 BW, respectively). The smallest vGRFs were recorded during the upper body exercises, cartwheel and handstand (1.3 ± 0.2 and 1.4 ± 0.2 BW, respectively), followed by the ginga and jump-lunge (1.4 ± 0.4 and 1.5 ± 0.6 BW, respectively). The fastest rate of force application was recorded for the jump-lunge (143.6 ± 144.9 BW·s^{-1}) followed by the 360° jump (132.4 ± 78.6 BW·s^{-1}) and the jump plus martelo (121.8 ± 93.5 BW·s^{-1}).

Discussion

Our aim was to determine the metabolic and musculo-skeletal load intensity of the CAPO Kids program; an in-school exercise intervention designed to improve the health of pre and early pubertal children. Specifically, our goal was to quantify energy expenditure and vertical ground reaction forces and rates of force application associated with a typical 10-minute intervention session of *capoeira* plus jumping.

We used SenseWear armbands to estimate energy expenditure of children participating in the school-based CAPO Kids exercise intervention program. We found that a single 10-minute bout of the intervention induced an absolute EE of 39.7 ± 9.3 kcal or 5.5 ± 0.9 METs, which represents an average EE of 4.0 kcal·min^{-1} (moderate intensity). Previous pediatric studies using the validated SWA algorithms to assess physical activity in children have reported EE for a variety of activities (Arvidsson et al., 2007; Calabró et al., 2009). For instance, the average EE for walking at 4 km·h^{-1} was 2.5 kcal·min^{-1} (low intensity), while the average for cycling was 3.0 kcal·min^{-1} (moderate intensity); both activities being less vigorous than the CAPO Kids intervention (Calabró et al., 2009). Activities such as basketball, running at 10 km·h^{-1}, and trampolining have been observed to consume more than 7 kcal/min, representing activities performed at a *vigorous* level (Arvidsson et al., 2007). While the average EE of a single bout of CAPO Kids was only 4.0 kcal·min^{-1} (*moderate* intensity), including short periods of rest, 34% of each 10-min session was spent performing activities at a *vigorous* or *very vigorous* level, suggesting the CAPO Kids program has the potential to provide a beneficial metabolic stimulus.

The maximal vGRFs produced by participants ranged from 1.3 BW for cartwheels to 5.4 BW for jumps and *capoeira* manoeuvres. The rates of force application varied from 15 BW·s^{-1} for cartwheels and *ginga* to around 140 BW·s^{-1} for jump-lunges and 360° jumps. Although the vGRF data presented represent a range of magnitudes and rates, five of the 11 measured activities produced vGRFs greater than 4.0 BW and six applied forces at more than 90 BW·s^{-1}. Ground reaction forces have been reported for other common activities such as walking, running, and drop jumps from different heights (Weeks and Beck, 2008, McKay et al., 2005), as well as specific high impact sports such as gymnastics and volleyball (Daly et al., 1999, Salci et al., 2004). Low impact activities generally produce lower GRFs, such as walking (i.e. 1.1 to 1.5 BW) and running (i.e. 2.0 to 3.0 BW), whereas high impact activities such as maximal jumping produce higher peak forces (i.e. 3.0 to 5.0 BW) (Weeks and Beck, 2008). Landings from heights above ground level generate even higher peaks that may reach more than 8.0 BW (Fuchs et al., 2002) with peak forces of up to 10.0 BW recorded for elite athletes from high impact sports such as volleyball and gymnastics (Daly et al., 1999, Salci et al., 2004).

Our GRF results were similar to those reported from other in-school pediatric jumping interventions, with beneficial musculoskeletal outcomes (McKay et al., 2005; Weeks et al., 2008). Those studies reported vGRFs between 3.0 and 5.0 BW from jumping activities such as hops, lunges and jump-squats in their intervention programs for children. Thus, the peak forces and rates of force application produced by the CAPO Kids exercises appear to be sufficiently high to be osteogenic.

The upper extremities are relatively unaccustomed to habitual impact loads and, accordingly, there are very few reports of the GRFs associated with upper limb weight-bearing activities. Forearm fractures, however, are highly prevalent in children (Khosla et al., 2003). As the bone response to mechanical loading is site-specific (Bass et al., 2002; Johannsen et al., 2003), it is important to specifically load the upper extremity to achieve adaptive benefits. We therefore also quantified the loads to which the upper limbs were exposed while weight-bearing during the CAPO Kids program. The upper extremity weight-bearing manoeuvres of handstands and cartwheels in the current study produced vGRFs of 1.3 and 1.4 BW, respectively. Although upper extremity GRFs of gymnasts performing elite level acrobatic movements have been reported up to 3.6 BW (Daly et al., 1999), our values nevertheless represent a large increase in loading to a region of the skeleton that is not typically exposed to weight bearing. Such loading was very simple and feasible for all of the children and may translate to considerable benefits in fracture prevention.

Limitations

For practical reasons, we used a light-weight, non-invasive, portable device to estimate EE, (i.e. armband sensor). We recognise that direct and indirect calorimetry remains the gold standard to estimate energy expenditure. Similarly, highly invasive techniques of direct measurement of bone strain were not feasible in the current cohort. GRFs were the best practical surrogate of musculoskeletal loading, but may not provide an entirely accurate estimate of the precise loads experiences by the skeleton.

Conclusion

We determined the metabolic and musculoskeletal load intensity of the CAPO Kids exercise intervention. We found that the CAPO Kids program has the ability to apply significant load intensity to both the metabolic and musculoskeletal systems of pre and early pubertal children. We conclude that the CAPO Kids program is likely to be an appealing, feasible and effective strategy to load the musculoskeletal and metabolic systems of children via in-school programming.

Acknowledgements

The authors wish to acknowledge the support and assistance provided by the teaching staff and administration at Guardian Angels Primary School. We would also like to extend our appreciation to the children who participated in the study and parents who brought their children to testing appointments on campus. Finally, we thank *Timezone* (Gold Coast, Australia) for providing incentive gifts to participants.

References

Arvidsson, D., Slinde, F., Larsson, S. and Hulthen, L. (2007) Energy cost of physical activities in children: validation of SenseWear Armband. *Medicine and Science in Sports and Exercise* **39,** 2076-2084.

Bass, S., Saxon, L., Daly, R., Turner, C., Robling, A., Seeman, E. and Stuckey, S. (2002) The effect of mechanical loading on the size and shape of bone in pre-, peri-, and postpubertal girls: a study in tennis players. *Journal of Bone and Mineral Research* **17(12),** 2274-2280.

Boreham, C. and Riddoch, C. (2001) The physical activity, fitness and health of children. *Journal of Sports Sciences* **19,** 915-29.

Calabró, M.A., Welk, G.J. and Eisenmann, J.C. (2009) Validation of the SenseWear Pro Armband algorithms in children. *Medicine and Science in Sports and Exercise* **41(9),** 1714-1720.

Daly, R.M., Rich, P.A., Klein, R. and Bass, S. (1999) Effects of high-impact exercise on ultrasonic and biochemical indices of skeletal status: A prospective study in young male gymnasts. *Journal of Bone & Mineral Research* **14,** 1222-1230.

Dunstan, D., Barr, E., Healy, G., Salmon, J., Shaw, J., Balkau, B., Magliano, D., Cameron, A., Zimmet, P. and Owen, N. (2010) Television viewing time and mortality the australian diabetes, obesity and lifestyle study. *Circulation* **121(3),** 384-391.

Fruin, M.L. and Rankin, J.W. (2004) Validity of a multi-sensor armband in estimating rest and exercise energy expenditure. *Medicine and Science in Sports and Exercise* **36,** 1063-1069.

Fuchs, R., Cusimano, B. and Snow, C.Y.F. (2002) Box jumping: A Bone-building exercise for elementary school children. *Journal of Physical Education, Recreation and Dance* **73(2)**, 22-25.

Guo, S.S., Wu, W., Chumlea, W.C. and Roche, A.F. (2002) Predicting overweight and obesity in adulthood from body mass index values in childhood and adolescence. *American Journal of Clinical Nutrition* **76(3)**, 653-658.

Haskell, W.L., Lee, I., Pate, R.R., Powell, K.E., Blair, S.N., Franklin, B.A., Macera, C.A., Heath, G.W., Thompson, P.D. and Bauman, A. (2007) Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise* **39,** 1423.

Jakicic, J.M., Marcus, M., Gallagher, K.I., Randall, C., Thomas, E., Goss, F.L. and Robertson, R.J. (2004) Evaluation of the SenseWear Pro Armband™ to assess energy expenditure during exercise. *Medicine and Science in Sports and Exercise* **36(5),** 897-904.

Janssen, I. (2007) Physical activity guidelines for children and youth *Applied Physiology, Nutrition, and Metabolism* **32,** S109-121.

Janz, K.F., Burns, T.L., Torner, J.C., Levy, S.M., Paulos, R., Willing, M.C. and Warren, J.J. (2001) Physical activity and bone measures in young children: the Iowa bone development study. *Pediatrics* **107,** 1387-1393.

Janz, K.F., Rao, S., Baumann, H.J. and Schultz, J.L. (2003) Measuring children's vertical ground reaction forces with accelerometry during walking, running, and jumping: The Iowa bone development study. *Pediatric Exercise Science* **15,** 34-43.

Johannsen, N., Binkley, T., Englert, V., Neiderauer, G. and Specker, B. (2003) Bone response to jumping is site-specific in children: a randomized trial. *Bone* **33(4),** 533-539.

Katzmarzyk, P.T., Church, T.S., Craig, C. L. and Bouchard, C. (2009) Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Medicine & Science in Sports & Exercise* **41(5),** 998-1005.

Khosla, S., Melton III, L.J., Dekutoski, M.B., Achenbach, S.J., Oberg, A.L. and Riggs, B.L. (2003) Incidence of childhood distal forearm fractures over 30 years: a population-based study. *The Journal of the American Medical Association* **290(11),** 1479-1485.

Lanyon, L.E. and Rubin, C. (1984) Static vs dynamic loads as an influence on bone remodelling. *Journal of Biomechanics* **17(12),** 897-905.

Magarey, A.M., Daniels, L.A., Boulton, T.J. and Cockington, R.A. (2003) Predicting obesity in early adulthood from childhood and parental obesity. *International Journal of Obesity* **27,** 505-513.

McKay, H., Tsang, G., Heinonen, A., Mackelvie, K., Sanderson, D. and Khan, K. (2005) Ground reaction forces associated with an effective elementary school based jumping intervention. *British Journal of Sports Medicine* **39(1),** 10-14.

Mirwald, R.L., Baxter-Jones, A.D., Bailey, D.A. and Beunen, G.P. (2002) An assessment of maturity from anthropometric measurements. *Medicine and Science in Sports and Exercise* **34(4),** 689-694.

Must, A. and Tybor, D. (2005) Physical activity and sedentary behavior: a review of longitudinal studies of weight and adiposity in youth. *International Journal of Obesity* **29,** S84-S96.

Nader, P.R., Bradley, R.H., Houts, R.M., Mcritchie, S.L. and O'Brien, M. (2008) Moderate-to-vigorous physical activity from ages 9 to 15 years. *The Journal of the American Medical Association* **300(3),** 295-305.

Nogueira, R.C., Weeks, B.K. and Beck, B. (2014) An in-school exercise intervention to enhance bone and reduce fat in girls: The CAPO Kids trial. *Bone* **68,** 92-99.

Nogueira, R., Weeks, B. and Beck, B. (2015) Targeting bone and fat with novel exercise for peripubertal Boys: The CAPO Kids trial. *Pediatric Exercise Science* **27**, 128-139.

Pearson, N. and Biddle, S.J. (2011) Sedentary behavior and dietary intake in children, adolescents, and adults: a systematic review. *American Journal of Preventive Medicine* **41(2),** 178-188.

Prapavessis, H. and McNair, P.J. (1999) Effects of instruction in jumping technique and experience jumping on ground reaction forces. *Journal of Orthopaedic & Sports Physical Therapy* **29(6),** 352-356.
Richard, R.M., Frederick, C.M., Lepes, D., Rubio, N. and Sheldon, K. M. (1997) Intrinsic motivation and exercise adherence. *International Journal of Sport Psychology* **28(4),** 335-354.
Salci, Y., Kentel, B.B., Heycan, C., Akin, S. and Korkusuz, F. (2004) Comparison of landing maneuvers between male and female college volleyball players. *Clinical Biomechanics* **19,** 622-628.
Specker, B.L., Johannsen, N., Binkley, T. and Finn, K. (2001) Total body bone mineral content and tibial cortical bone measures in preschool children. *Journal of Bone & Mineral Research* **16(12),** 2298-305.
St-Onge, M., Mignault, D., Allison, D.B. and Rabasa-Lhoret, R. (2007) Evaluation of a portable device to measure daily energy expenditure in free-living adults. *American Journal of Clinical Nutrition* **85(3),** 742-749.
Strong, W.., Malina, R.M., Blimkie, C.J.R., Daniels, S.R., Dishman, R.K., Gutin, B., Hergenroeder, A.C., Must, A., Nixon, P.A. and Pivarnik, J.M. (2005) Evidence based physical activity for school-age youth. *Journal of Pediatrics* **146(6),** 732-737.
Tremblay, M.S., Leblanc, A.G., Kho, M.E., Saunders, T.J., Larouche, R., Colley, R.C., Goldfield, G. and Gorber, S.C. (2011a) Systematic review of sedentary behaviour and health indicators in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity* **8,** 98.
Tremblay, M.S., Warburton, D.E., Janssen, I., Paterson, D.H., Latimer, A.E., Rhodes, R.E., Kho, M.E., Hicks, A., Leblanc, A.G. and Zehr, L. (2011b) New Canadian physical activity guidelines. *Applied Physiology, Nutrition, and Metabolism* **36,** 36-46.
Twisk, J.W. (2001) Physical activity guidelines for children and adolescents. *Sports Medicine* **31(8),** 617-627.
Weeks, B.K. and Beck, B.R. (2008) The BPAQ: a bone-specific physical activity assessment instrument. *Osteoporosis International* **19,** 1567-77.
Weeks, B.K., Young, C.M. and Beck, B.R. (2008) Eight months of regular in-school jumping improves indices of bone strength in adolescent boys and girls: the POWER PE study. *Journal of Bone and Mineral Research* **23(7),** 1002-11.

Key points

- Energy expenditure of a single bout of CAPO Kids yields 39.7±9.3 kcal and includes activities performed at a vigorous and very vigorous intensity.
- Mechanical loads associated with CAPO Kids surpass five times bodyweight and more than 140 bodyweights per second.
- CAPO Kids intervention represents a viable approach to stimulate musculoskeletal and metabolic adaptation in children.

AUTHOR BIOGRAPHY

Rossana Candiota NOGUEIRA
Employment
School of Allied Health Sciences, Griffith University Gold Coast campus, QLD, Australia
Degree
BHMS(Ed), MSc, PhD
Research interests
Exercise physiology; Effects of exercise on bone health, body composition
E-mail: rossana.nogueira@gmail.com

Benjamin K. WEEKS
Employment
School of Allied Health Sciences, Griffith University Gold Coast campus, QLD, Australia
Degree
BPhty(Hons), BExSc, GCertHigherEd, PhD
Research interests
Physical activity and musculoskeletal health; Maximising peak bone mass in children; and quantifying physical activity participation.
E-mail: b.weeks@griffith.edu.au

Belinda R. BECK
Employment
School of Allied Health Sciences, Griffith University Gold Coast campus, QLD, Australia
Degree
BHMS(Ed), MS, PhD
Research interests
Effects of mechanical loading on bone, prevention of osteoporosis and stress fractures, exercise interventions
E-mail: b.beck@griffith.edu.au

✉ **Belinda R. Beck**
Employment: School of Allied Health Sciences, Griffith University Gold Coast campus, QLD 4222, Australia