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Effect of a time efficient physical activity intervention on senior school students' on-task behaviour and subjective vitality: The 'Burn 2 Learn' cluster randomised controlled trial

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Abstract

Despite well-established benefits, the majority of young people around the globe are not sufficiently active. In many countries, including Australia, physical activity (i.e., physical education and school sport) is not mandatory in the final two years of high school (i.e., senior school years). The aim of this study was to assess the impact of a time efficient physical activity intervention on senior school students' on-task behaviour and subjective vitality. This was a sub-study of the Burn 2 Learn (B2L) cluster randomised controlled trial, which included two cohorts. Participants for this sub-study ($N = 221$) were from 10 secondary schools (23 classes) located in New South Wales, Australia (Cohort 2). Teachers allocated to the B2L intervention group were provided with training, resources and support to facilitate the delivery of two high intensity activity breaks per week during lesson-time for five weeks. On-task behaviour was assessed at baseline and post-test, using a momentary time sampling procedure and expressed as a percentage of lesson time. At post-test, subjective vitality was assessed at the start and end of the lesson using a validated questionnaire. Significant group-by-time effects were observed for students' on-task behaviour in favour of the B2L group [adjusted mean difference = 18.9% (95% CI, 3.2 to 34.6), $p = .020$, $d = 0.4$]. At post-test, significant group-by-time effects were observed for students' subjective vitality favouring the B2L group [adjusted mean difference = 0.71 (95% CI, 0.28 to 1.14), $p = .003$, $d = .02$]. The B2L intervention was successful in improving senior school students' on-task behaviour and their subjective vitality. These findings highlight the potential academic benefits of re-allocating curriculum time to physical activity during the senior school years.

Introduction

Participation in physical activity decreases rapidly during adolescence and less than 20% of adolescents across the globe are sufficiently active (Bai, Chen, Vazou, Welk, & Schaben, 2015; Dumith, Gigante, Domingues, & Kohl III, 2011; Hallal et al., 2012; Schranz et al., 2018). Physical activity is particularly important for young people's physical (e.g., prevention of chronic cardiovascular diseases such as blood pressure, insulin resistance and obesity) (Janssen & LeBlanc, 2010) and mental health, eliciting improvements in well-being (e.g., self-perception, self-esteem, happiness and self-regulation) and reducing the prevalence and severity of ill-being (e.g., depression, anxiety, stress and suicide) (Biddle & Asare, 2011; Landers & Arent, 2007; Penedo & Dahn, 2005). In addition, physical activity has been linked to improvements in cognition, metacognition, school and academic achievement (Álvarez-Bueno et al., 2017; Babic et al., 2014; de Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2018; Khan & Hillman, 2014; D. Lubans et al., 2016; Singh et al., 2019). A range of neurobiological, behavioural, and psychosocial mechanisms may explain the positive effects of physical activity on cognitive and mental health in children and adolescents (D. Lubans et al., 2016).

According to the neurobiological hypothesis, participation in physical activity can alter the structural and functional composition of specific brain regions (e.g., neuroplasticity and neurogenesis, improved blood flow and oxygenation) that support attention, memory, and learning (D. Lubans et al., 2016; Mavilidi et al., 2018; Voss, Vivar, Kramer, & van Praag, 2013). Neuroimaging studies in children have found a significant and positive association between participation in physical activity and different brain outcomes (e.g., white matter integrity, brain volume and function) derived using various neuroimaging methods (e.g., structural and functional magnetic resonance imaging, event-related potentials) (D. Lubans et al., 2016; Valkenborghs et al., 2019). For example, Chaddock-Heyman et al. (2013) reported that children who participated in the 9-month FitKids physical activity program improved their performance on cognitive tasks and demonstrated more mature brain activation patterns in the right anterior prefrontal cortex.

Regarding potential behavioural mechanisms, participation in physical activity has an acute effect on students' engagement in the classroom, often reflected in improvements in 'time on-task' and concentration (Owen et al., 2016). Although concentration refers to a cognitive aspect of engagement and can be defined as the action of focusing attention, it is often conceptualised as behavioural engagement (Fredricks, Blumenfeld, & Paris, 2004). Alternatively, behavioural disengagement refers to reduced effort and participation in school activities, usually evaluated via measurement of students' time off-task, fidgeting and inattention (Fredricks et al., 2004). Thus, student engagement, usually called 'on-task behaviour' and 'time-on-task', is a key factor influencing academic success by minimising classroom disruptions (J.E. Donnelly & Lambourne, 2011; Greenwood, Horton, & Ytlley, 2002).

There is compelling evidence supporting the efficacy of school-based physical activity interventions (i.e., active recess, active lessons and physically active breaks) for improving children's on-task behaviour (Owen et al., 2016; Watson, Timperio, Brown, Best, & Hesketh, 2017). Based on the findings from a recent systematic review and meta-analysis, single bouts of moderate-to-vigorous intensity physical activity produce small-to-moderate positive effects on students' on-task behaviour ($d = .43$) (Owen et al., 2016). In particular, classroom activity breaks appear to have the largest effect on student behaviour (Watson et al., 2017). For example, Mahar and colleagues demonstrated that 10-minute classroom-based physical activity breaks delivered during lesson time, increased children's on-task behaviour by 8.3% (M.T Mahar et al., 2006). However, the majority of this research has involved activity of moderate intensity and no studies have been conducted with adolescents in secondary schools (Goh, Hannon, Webster, Podlog, & Newton, 2016; Grieco, Jowers, & Bartholomew, 2009; Matthew T. Mahar, 2019; Mavilidi et al., in press; Riley, Lubans, Holmes, & Morgan, 2016; Stewart et al., 2019; Szabo-Reed et al., 2019).

Regarding potential psychosocial mechanisms, the acute effect of physical activity on students' mood or affect may support student engagement in the classroom. In an attempt to explain the relationship between physical activity and affective responses, Ekkekakis proposed the Dual Mode Theory (DMT) (Panteleimon Ekkekakis, 2003). According to DMT, affective responses to exercise are influenced by the interplay between two factors, namely cognitive parameters (e.g., self-efficacy) and interoceptive cues (e.g., signals from chemoreceptors and baroreceptors) (Panteleimon Ekkekakis, Parfitt, & Petruzzello, 2011). The balance between these factors change as a function of exercise intensity, with cognitive factors more dominant at low intensities, while introceptive cues become more salient as individuals reach their functional limits (i.e., ventilatory threshold) (Panteleimon Ekkekakis, 2003). There is an almost universally positive affective response to light activity, while high intensity activity typically evokes feelings of displeasure (Panteleimon Ekkekakis, 2003; P. Ekkekakis, Hall, & Petruzzello, 2005; Parfitt & Hughes, 2009). However, several studies have found a positive "rebound effect" following the cessation of high-intensity activity (Jung, Bourne, & Little, 2014; Malik, Williams, Weston, & Barker, 2019). These studies have noted initial decreases in affect during high intensity activity following by improvements in affect beyond baseline values after a period of about 20 minutes.

Building on the DMT, the circumplex model includes dimensions of affective valance (from pleasure to displeasure) and perceived activation (from activated to deactivated) (Panteleimon Ekkekakis & Petruzzello, 2002). A meta-analysis conducted by Reed and Ones (2006) found a moderate effect (ES = .47) of exercise on 'positive activated affect' (i.e., feeling good with high levels of activation) (Reed & Ones, 2006). The construct of subjective vitality captures both dimensions of affective valence and perceived activation and has been defined by Ryan and Frederick (1997, p. 530) as “one’s conscious experience of possessing energy and aliveness, enthusiasm and spirit”. Because of its positive association with physical and psychological parameters, subjective vitality may represent a significant indicator of personal well-being (Ryan & Frederick, 1997). Evidence for the positive effect of physical activity on subjective vitality and on-task behaviour may act as novel ‘hook’ for schools to take interest in and implement physical activity interventions with a long-term goal to improve academic performance. Identifying time efficient solutions is a global priority because lack of time is the most commonly cited barrier to the implementation of school-based physical activity interventions (Naylor et al., 2015),

High-intensity interval training has emerged as a novel and time-efficient option for promoting physical activity in schools and improving academic outcomes (Bond, Weston, Williams, & Barker, 2017; Costigan, Eather, Plotnikoff, Taaffe, & Lubans, 2015). It involves relatively short intervals of high-intensity activity (i.e., >85% max heart rate), interspersed with periods of active recovery or rest. Systematic review evidence suggests that high-intensity physical activity can positively benefit a range of cardio-metabolic outcomes in adolescents (Costigan et al., 2015; Logan, Harris, Duncan, & Schofield, 2014). Also, experimental studies have found cognitive and mental health benefits of high-intensity physical activity (Costigan, Eather, Plotnikoff, Hillman, & Lubans, 2016; A. Leahy et al., 2019). For example, a 6-week intervention involving high-intensity physical activity breaks (i.e., 10 minutes) for five times per week, revealed significant improvements in children and adolescents’ cognitive control and working memory (Moreau, Kirk, & Waldie, 2017).

Burn 2 Learn (B2L) is a time efficient physical activity intervention for senior schools students and is currently being evaluated in a cluster randomised controlled trial in 20 secondary schools (A. A. Leahy et al., 2019). Teachers from the intervention schools are provided with training, resources and support to facilitate the delivery of at least two high intensity activity breaks per week over the study period (two school terms). The current investigation is a sub-study of the larger cluster RCT, designed to explore the impact of the intervention on senior school students' on-task behaviour. A secondary aim was to measure the acute effects of the intervention on students' subjective vitality. To the authors' knowledge this is the first study to assess the effects of a high intensity physical activity intervention on senior school students' on-task behaviour and subjective vitality.

Methods

Study design

This was a sub-study of the B2L cluster randomised controlled trial. Full details of the study protocols and pilot findings from the B2L program are reported elsewhere (A. Leahy et al., 2019). The design, conduct and reporting of the trial adhered to Consolidated Standards of Reporting Trials (Moher et al., 2010) and the Template for Intervention Description and Replication (Hoffmann et al., 2014). The trial was prospectively registered with the Australian and New Zealand Clinical Trials Registry (ACTRN12617000544370). Participants were recruited from 20 New South Wales (NSW) government schools and data were collected in two cohorts (Cohort 1: February 2018 – February 2019; Cohort 2: February 2019 – February 2020). The current study included participants from Cohort 2 only (N = 221 senior school students, Grades 11 and 12, students aged 16-18 years). This sub-study included ten government schools located within 150 minutes' drive from the University of Newcastle (e.g., Hunter-Central Coast, Sydney, Northern Sydney, and Western Sydney regions). These areas are broadly representative of urban and regional secondary schools in NSW, Australia.

Once schools expressed an interest in the study, the Project Manager met with school representative(s) and explained the study requirements. At this time, schools were asked to identify two Grade 11 teachers willing to facilitate the delivery of the scheduled B2L sessions during timetabled curricular time. There were no subject restrictions (e.g., Mathematics, English, Science, Health and Physical Education) regarding the two teachers eligible for study participation.

Participants

A total of 23 Grade 11 teachers (three additional teachers were included due to small class sizes) willing to facilitate the B2L sessions during class time were recruited to participate in the study. All Grade 11 students taught by their Grade 11 teachers were eligible for participation in the study. Students that consented to participate in the B2L intervention also consented to participate in the evaluation component (i.e., student consent rate for Cohort 2 was 73.0%). Ethics approval for the B2L cluster RCT was granted by the Human Research Ethics Committee of the University of Newcastle, Australia, and the NSW Department of Education.

Randomisation

Once baseline data were collected, schools were matched according to the following criteria: geographic location, socio-economic status, student population educational advantage (using the Areas Index of Relative Socio-Economic Disadvantage; Australian Bureau of Statistics, 2001) and subject area (e.g., Mathematics, English, etc.). A school from each pair was then randomised to the B2L intervention or the ‘wait list control’ group by an independent researcher not involved in the study using a computer-based random number generator.

Design and procedure

The intervention was designed in consultation with the NSW Department of Education and guided by the Consolidated Framework for Implementation Research (Damschroder et al., 2009) to maximise scalability and sustainability.

Teacher training: Teachers were provided with training, resources and support to facilitate the delivery of at least two high-intensity activity breaks per week during curriculum time (A. A. Leahy et al., 2019). Before the beginning of the intervention, teachers participated in a 6-hour professional development workshop, conducted at the University of Newcastle. During the workshop, teachers were provided with evidence supporting the benefits of vigorous physical activity and cardiorespiratory fitness for cognitive and mental health and key teaching strategies to facilitate the delivery of B2L sessions. In addition, teachers participated in practical activity breaks sessions using the B2L resources (i.e., task cards and smartphone application). The professional learning workshop also included the creation of action plans for teachers. The action plans highlighted the timeline, example of activities as well as potential barriers and solutions to implementation. At the end of the session, teachers were provided with a B2L equipment package ($AUS 2,500) including 1 x heart rate monitor per student, 1 x Bluetooth speaker, 1 x WASP device (i.e., Bluetooth enhancer), and a selection of sports equipment (e.g., balls, cones).

Intervention delivery: Teachers were asked to facilitate the delivery of at least two activity breaks sessions/week during lesson time, using the program resources (i.e., videos, presentations slides, task cards - Gym, Sport, Combat, Class, Quick, Hip Hop, Brain, Rumble, Beach, Custom), giving an option to teachers to use a variety of activity breaks (e.g., type of activity, music playing, and training partner). The duration of each activity break session was approximately 8-20 minutes.

A bespoke B2L app was designed to facilitate the delivery of the intervention. Features of the app include: i) description of a variety of different activity breaks (e.g., Gym, Sport, etc), ii) options for 'solo', 'group', or ‘class’ sessions utilising Bluetooth heart rate monitoring, (iii) timer, audible prompts and display of heart rate during activity breaks, (iv) personalised post-session reports outlining heart rate average and peak heart rate (both at individual and whole class level), and (v) display of session log on app dashboard. Students’ participation in the activity breaks were tracked using the B2L app and via teacher-reported session logs.

The delivery of the B2L sessions was guided by “Supportive, Active, Autonomous, Fair, and Enjoyable” (SAAFE) physical activity delivery principles (D. R. Lubans et al., 2017) and were logged on the app’s dashboard. Aligned with self-determination theory, the B2L intervention was designed to promote students’ autonomous motivation for vigorous physical activity within and beyond the school setting, fulfilling their basic psychological needs for autonomy (feeling in control), competence (feeling capable), and relatedness (feeling connected with others) (Deci & Ryan, 2008).

The *control group* continued with usual school practice (i.e., normal curricular lessons) for the duration of the study period. Schools in the “wait-list control” condition will be offered the intervention following final assessments of the full B2L study (12-months). The wait-list control design was considered preferable to an attention-matched placebo because, the intervention was delivered by teachers, rather than members of the research team (who had minimal contact with students).

Measures

Baseline assessments were conducted as part of the B2L cluster RCT in Weeks 6-10 of school Term 1 (February- March 2019) before randomisation. Post-test assessments for this sub-study were conducted in weeks 5-6 of school Term 2 (May 2019). Demographic information regarding students' age, cultural background, language spoken at home, socioeconomic status, and weight status was collected at baseline via online questionnaires. Students' on-task behaviour was observed by trained research assistants in both groups at baseline and post-test. It was not possible to blind assessors to treatment allocation at follow-up because the activity breaks were occurring during the observation period. The same observers were used at both time-points. Students in both groups completed the vitality questionnaire twice at post-test (start and end of the lesson). Consenting students completed assessments under exam-like conditions following a verbal explanation from a research assistant.

On-task behaviour: Classroom observations were conducted during scheduled class times using a momentary time sampling procedure adopted from the *Behaviour Observation of Students in Schools* and *the Applied Behaviour Analysis for Teachers* (Alberto & Troutman, 2003; Shapiro & Cole, 1994). On-task behaviour includes times when the child is actively engaged in an academic activity (e.g., reading, writing, or performing the designated task), rather than passively engaged (e.g., sitting quietly, but not engaged in the activity) or disruptive behaviour. Off-task behaviour is related to behaviour not associated with the task such as off-task motor (e.g., walking around the classroom), off-task verbal (e.g., talking) and off-task passive (e.g., staring out the window). Observations started 10 min after the students entered the classroom (i.e., 10 min after start of lesson at baseline and in control schools, or 10 min after completion of physical activity breaks in the intervention schools). Mahar (2019) suggests that assessments be conducted 30 min before and after physical activity. However, this was not possible in this study as students in this age group change classrooms and teachers at the end of each 45-60 min lesson. Researchers observed 12 randomly selected students in each lesson (six students per research assistant) where possible.

Observations were conducted at the end of 15 sec intervals, with the observed student coded as being on-task (actively engaged or passively engaged), or off-task (off-task verbal, off-task motor or off-task passive) at the time. At the end of the following 15 sec interval, the next student's behaviour was coded. Observers listened to an MP3 audio file via headphones, which informed them when to observe and record by circling an appropriate code (i.e., actively engaged, passively engaged or off-task) using an observation sheet. This process repeated until each of the six students had been observed 20 times (during a 30 min observation period) on a rotational basis. Two trained research assistants were responsible for conducting all observations and inter-rater reliability scores were established in the training phase (intra-class correlation coefficient = 0.84). Regarding inter-rater reliability 85% is considered acceptable, while agreement less than 70% warrants concerns (Matthew T. Mahar, 2019; van Houten & Vance Hall, 2001).

Subjective vitality was measured at the start (as soon as students entered the room) and end of regular timetabled lessons (i.e., after 45-60 min) under exam like conditions using the 6-item questionnaire developed by Ryan and Frederick (1997) at post-test only. Students were asked to respond to a series of statements about how they were currently feeling (e.g., "At this moment, I feel alive and vital"). Items were scored on a 7-point Likert scale, ranging from 1, *Not at all true* to 7, *Very true*.

Intervention dose and fidelity

Intervention dose and fidelity were determined by examining:

(i) *Dose (number of sessions):* Teachers were asked to record every activity break session they delivered in the B2L teacher handbook.

(ii) *Fidelity (session intensity):* During activity break sessions students wore Wahoo TICKR heart rate monitors, which were connected to a purpose-built iPad application (B2L). Mean peak heart rate (% maximum) and mean heart rate for the entire session (% maximum) were monitored during the sessions.

(iii) *Fidelity (session quality):* The quality of the activity breaks was assessed by members of the research team, who conducted one SAAFE observation (D. R. Lubans et al., 2017) for each teacher during the sub-study period.

Statistical analyses

Statistical analyses were conducted using IBM SPSS (version 24) and alpha levels were set at $p > 0.05$. The outcomes were analysed using linear mixed models, which are (i) consistent with the intention-to-treat principle, (ii) robust to the biases of missing data and (iii) provide appropriate balance of Type 1 and Type 2 errors (Krull & MacKinnon, 2001; Mallinckrodt, Watkin, Molenberghs, & Carroll, 2004). Considering the hierarchical structure of the data (e.g., students nested within classes and schools), multilevel modelling analyses were used to analyse all outcomes (Raudenbush & Bryk, 2002). More specifically, the models were adjusted for the clustering at class level, as previous studies have shown that school-level clustering is negligible after accounting for clustering at the class level (Rosenkranz et al., 2012). Sensitivity analyses were conducted to confirm this assumption with the B2L study data. The dependent variables were students' on-task behaviour and their subjective vitality scores. Cohen's *d* was calculated to provide a measure of effect size (adjusted difference between B2L and control group over time divided by the pooled standard deviation of change) and defined as small ($d = 0.2$), medium ($d = 0.5$) or large ($d = 0.8$).

Results

Overview

A summary of the demographic characteristics is presented in Table 1. The majority of the participants were: born in Australia (80.1%), spoke English at home (88.2%), and were from an Australian background (56.1%). In addition, the majority of participants were classified as having a healthy weight status (65.2%).

On-task behaviour

Intervention effects are presented in Table 2. Significant group-by-time effects were observed for students' overall on-task behaviour in favour of the B2L group [adjusted mean difference = 18.9% of lesson time (95% CI, 3.2 to 34.6), p = .020, d = 0.4]. More specifically, significant group-by-time effects were observed for students' active engagement in favour of the B2L group [adjusted mean difference = 21.1% (95% CI, 6.8 to 35.4), p = .005, d = 0.3]. The group-by-time effect for passive engagement was not statistically significant.

Significant group-by-time effects were observed for off-task behaviour, favouring the B2L group [adjusted mean difference = -19.1% (95% CI, -34.8 to -3.4), p = .019, d = -0.4]. When examining each sub-category, there were no significant group-by-time effects for off-task verbal, or off-task motor. However, off-task passive behaviour was reduced, with reductions favouring the intervention group [adjusted mean difference = -11.8% (95% CI, -18.7 to -5.0), p = .002, d = -0.2].

Subjective vitality

At post-test, significant group-by-time effects were observed for students' subjective vitality in favour of the B2L group [adjusted mean difference = 0.71 units (95% CI, 0.28 to 1.15), p = .003, d = .02].

Intervention dose and fidelity

According to teacher logs, students completed an average of 1.8 sessions/week. Data from the heart rate monitors (via the B2L app) showed the. The mean peak heart rate was 82.9% (SD = 9.5) max and the mean heart rate for all sessions was 71.3% (SD = 10.6) max. Researcher fidelity observations of the B2L practical sessions using the SAAFE principles

(D. R. Lubans et al., 2017) showed that activity breaks were: Supportive (3.4/5 units; *SD* = 0.69), Active (3.1/5 units; *SD* = 0.89), Autonomous (2.0/5 units; *SD* = 0.96), Fair (3.5/5 units; *SD* = 0.90), and Enjoyable (2.6/5 units; *SD* = 1.02), with a high overall score (14.1/20 units; *SD* = 3.49).

Discussion

This sub-study was designed to investigate the effect of the B2L intervention on senior school students' on-task behaviour and subjective vitality. Significant group-by-time effects were observed for students' on-task behaviour and their subjective vitality. These findings indicate that students: (i) were more actively engaged during classroom-based lessons and (ii) experienced improvements in aliveness and energy, after participating in activity breaks at the start of their lessons. Together these outcomes provide evidence for the potential academic benefits of allocating curriculum time to brief physical activity breaks in the senior school years.

Improvements in on-task behaviour can lead to enhanced academic performance (J.E. Donnelly & Lambourne, 2011; Greenwood et al., 2002). The current study builds upon existing research supporting the benefits of school-based physical activity (e.g., activity breaks) for improving student engagement in children, by extending these findings to senior school students. Studies conducted with primary school children have demonstrated that short active breaks can improve students' on-task behaviour during academic lessons (Carlson et al., 2015; Grieco et al., 2009; Ma, Le Mare, & Gurd, 2014; M.T Mahar et al., 2006; Mavilidi et al., in press; Szabo-Reed et al., 2017). Similar to studies conducted with children in primary schools (ES = 0.32 - 0.60; Bartholomew et al., 2018; M.T Mahar et al., 2006; Mullender-Wijnsma et al., 2016), the current study found a moderate effect size for improvements in on-task behaviour (ES = 0.4).

The current study provides unique evidence for the benefits of high-intensity activity for classroom engagement, as the majority of previous studies have utilised physical activity of moderate intensity (Bartholomew et al., 2018; Grieco et al., 2009; M.T Mahar et al., 2006; Mavilidi et al., in press; Riley et al., 2016; Stewart et al., 2019; Szabo-Reed et al., 2017). Currently, only one study has evaluated the effect of high-intensity physical activity breaks in children (i.e., 20s of high intensity followed by 10s of rest, with a total of 4 min) and found significant decreases in off-task behaviour (Ma et al., 2014).

Results from this study suggest that participation in high intensity activity breaks can reduce students' off-task behaviour. In particular, significant group-by-time effects were found for students' off-task passive behaviour (such as for example, gazing off, staring into space, head down on the desk), while off-task motor (e.g., fidgeting, drawing, being restless) and off-task verbal behaviours (e.g., chatting) did not change. Research using activity breaks of moderate (M.T Mahar et al., 2006) and vigorous (Ma et al., 2014) intensity have identified the largest improvements in on-task behaviour among the most disruptive students. Although this was not explored in the current study, future research is needed to test the effects of activity breaks in classes with disruptive adolescent students or students with poor academic results.

A recent systematic review and meta-analysis examining the acute effects of high-intensity exercise on executive function found stronger effects for high intensity activity (~77% to 88.5% heart rate max), compared to activity of very high (~88.6% to 99.9% heart rate max) to maximal (100% heart rate max) intensity (Moreau & Chou, 2019). The same review noted that brief exercise sessions (i.e., 6 to 10 min) produced similar effects to sessions lasting 20 minutes or more. Although cognitive function was not measured in the current study, the intensity and duration of the B2L sessions (i.e., mean peak heart rate 82.9% max and 8 min duration) was consistent with these characteristics, suggesting possible benefits for students' cognitive function. Considering the potent gains arising from participation in shorter bouts of high intensity physical activity such as improvements in fitness, mental and cognitive health (Joseph E Donnelly et al., 2016; D. Lubans et al., 2016; Ruiz et al., 2010), high-intensity activity breaks may provide a more sustainable 'value for money' strategy in comparison to low- and moderate-intensity breaks of longer duration.

To the authors' knowledge, this is the first study to demonstrate that participation in high intensity activity breaks can improve adolescents' subjective vitality. Previous research conducted with adolescents (Costigan et al., 2016; Malik et al., 2019) has used the Feeling State (Charles & Rejeski, 1989) and Felt Arousal (Svebak & Murgatroyd, 1985) scales. Feelings of vitality are thought to be influenced not only by somatic experience, but also by the interpretation of the experience as beneficial or detrimental with respect to the self (Ryan & Frederick, 1997). Accordingly, one's motivation toward exercise is likely to influence its subsequent impact on subjective vitality. For this reason, students who are intrinsically motivated toward exercise are more likely to be vitalised by the experience, compared to those who have been forced to participate (Nix, Ryan, Manly, & Deci, 1999). As such, the current study was designed in accordance with SAAFE principles and the sessions were designed to be 'autonomous supportive' (D. R. Lubans et al., 2017). Furthermore, teachers were encouraged to remind students to reflect upon their feeling state after completing the exercise sessions. However, according to the SAAFE observation results, teachers provided sub-optimal levels of autonomy and enjoyment in the exercise sessions. Further training and attention may be needed for teachers to effectively implement these strategies during high intensity exercise.

Subjective vitality may act as a mechanism to explain the positive effect of physical activity on academic outcomes. Pastor and colleagues (2019) suggested that acute physical exercise before the execution of high cognitive inhibition tasks may improve vitality and cognitive performance (Pastor, Cervelló, Peruyero, Biddle, & Montero, in press). Affect has been related to several academic outcomes such as motivation, engagement and achievement (Ahmed, van der Werf, Kuyper, & Minnaert, 2013; Pekrun & Linnenbrink-Garcia, 2012). In particular, a recent study found that positively motivated students were more engaged in lessons and received higher grades (Robinson et al., 2017). The current study contributes to the existing findings by providing preliminary evidence for the impact of high-intensity activity on subjective vitality, which may indirectly influence academic achievement.

Research has demonstrated that classroom teachers are more likely to implement physical activity interventions when they have a clear focus on academic-related outcomes (Bartholomew et al., 2018; Mahar, 2019). As such, the use of activity breaks for improving adolescents' mental health, including psychological well-being and cognitive function, may be a particularly appealing approach for teachers, holding promise for its sustainability in the long-term. In addition, Mahar (2009) has noted that it is necessary to provide teachers with the appropriate resources and training, as well as address their perceptions and potential barriers related to the implementation of activity breaks in schools. Of note, the B2L intervention was guided by the Consolidated Framework of Implementation Research strategies (Damschroder et al., 2009) and teachers were provided with training, research and support to deliver high-intensity activity breaks. In addition, the research team developed the intervention in collaboration with the NSW Department of Education, with the focus on potential scale-up and dissemination. Despite these strategies, anecdotal feedback from teachers indicated that the time taken to complete the sessions, most likely linked with technological issues using the app and heart rate monitors, was a barrier to the completion of activity breaks.

Strengths and limitations

The strengths of this trial include the cluster randomised controlled design, high degree of intervention fidelity, unique study population and novel intervention design. Importantly, B2L represents a new physical activity opportunity for senior school students. Although schools are recognised as ideal settings for physical activity promotion (Hills, Dengel, & Lubans, 2015), the majority of secondary schools around the world do not provide mandatory physical activity opportunities (i.e., physical education and school sport) for senior students (Hardman, Murphy, Routen, & Tones, 2013). In addition, previous school-based physical activity interventions targeting adolescents have been largely ineffective (Borde, Smith, Sutherland, Nathan, & Lubans, 2017; Metcalfe, Henley, & Wilkin, 2012). As such, there is an urgent need to explore novel intervention strategies to provide older adolescents with a dose of health-enhancing physical activity (Office of Disease Prevention and Health Promotion, 2018).

Despite these strengths, there are some study limitations that should be acknowledged. First, it was not possible to maintain researcher blinding at post-test because the activity breaks were taking place during the lessons. Second, previous research has measured on-task behaviour before and after physical activity (Bartholomew et al., 2018; M.T Mahar et al., 2006). This approach was not feasible for this study, as students move between classes and change teachers in secondary schools. Thus, on-task behaviour was measured directly after the activity breaks sessions (10 min after students entered the classroom). Third, due to a number of students leaving school, not all students were assessed at post-test. It is important to note that the study time-period (i.e., Grade 11) includes the transition to work for some students. Fourth, the duration of the study period was relatively short and no long-term follow-ups were conducted. Finally, improvements in subjective vitality may be due to “expectation bias” (Molendijk, Fried, & Van der Does, 2018). In the first week of the intervention students in the B2L group participated in an information session, which focused on the benefits of physical activity for cognitive and mental health. This may have producing a “priming effect”, whereby students in the intervention group were more likely to report improvements in subjective vitality after participating in the activity breaks.

Conclusion

The benefits of physical activity and for young people transcend physical, social, psychological and cognitive domains. The B2L intervention presents a feasible and practical approach to provide older adolescents with a dose of physical activity to address the decline in behaviour that is typically observed during this period. This study showed that short high-intensity physical activity breaks improved students’ on-task behaviour and their subjective vitality. These findings highlight the potential academic benefits of re-allocating curriculum time to physical activity during the senior school years. Future research is needed to determine if these positive effects extend to improvements in academic achievement over longer study periods.

Table 1: *Characteristics of study sample*

Characteristics	Total (n = 221)	Control (n = 107)	B2L (n = 114)
Age, mean (SD), y	16.0 (0.5)	16.0 (0.5)	16.1 (0.5)
Female participants, n (%)	110 (49.8)	46 (43.0)	64 (56.1)
Born in Australia, n (%)	177 (80.1)	90 (84.1)	87 (76.3)
English spoken at home, n (%)	195 (88.2)	101 (94.4)	94 (82.5)
Cultural background, n (%)			
Australian	124 (56.1)	65 (60.7)	59 (51.8)
European	31 (14.0)	14 (13.1)	17 (14.9)
African	4 (1.8)	2 (1.9)	2 (1.8)
Asian	24 (10.9)	6 (5.6)	18 (15.8)
Middle Eastern	2 (0.9)	0 (0.0)	2 (1.8)
Other	36 (16.3)	20 (18.7)	16 (14.0)
Indigenous decent, n (%)	19 (8.6)	7 (6.5)	12 (10.5)
Socioeconomic status Area, n (%)[a]			
Low	34 (15.4)	16 (15.0)	18 (15.8)
Medium	72 (32.6)	29 (27.1)	43 (37.7)
High	115 (52.0)	62 (57.9)	53 (46.5)
Weight status, n (%)[b]			
Underweight	13 (5.9)	9 (8.4)	4 (3.5)
Healthy weight	144 (65.2)	63 (58.9)	81 (71.1)
Overweight	42 (19.0)	23 (21.5)	19 (16.7)
Obese	19 (8.6)	10 (9.3)	9 (7.9)

[a] Socioeconomic status determined by population tertile using Socio-Economic Indexes For Areas of relative socioeconomic disadvantage based on residential postcode
[b] Three participants were not measured for weight status.

Table 2. *Summary of outcome measures for on-task behaviour*

Outcomes	**Group**	**Baseline M (95% CI)**	**Post-test M (95% CI)**	**Time *p***	**Adj. diff. in change (B2L – CON)**	**Group-by-time p**	**Group-by-time *d***
On-task behaviour	CON	63.01 (54.73 to 71.29)	61.42 (53.01 to 69.82)	0.771	18.88 (3.19 to 34.57)	**0.020**	0.4
	B2L	61.38 (53.18 to 69.58)	78.67 (70.29 to 87.05)	0.004			
Actively engaged	CON	33.20 (25.07 to 41.34)	29.59 (21.34 to 37.84)	0.470	21.09 (6.80 to 35.37)	**0.005**	0.3
	B2L	30.75 (22.71 to 38.80)	48.23 (40.01 to 56.45)	< 0.001			
Passively engaged	CON	29.84 (21.40 to 38.29)	32.17 (23.62 to 40.71)	0.663	-2.59 (-17.91 to 12.73)	0.730	0.1
	B2L	30.61 (22.27 to 38.95)	30.34 (21.84 to 38.84)	0.959			
Off-task behaviour	CON	36.83 (28.60 to 45.07)	38.40 (30.04 to 46.76)	0.773	-19.11 (-34.79 to -3.44)	**0.019**	-0.4
	B2L	38.92 (30.76 to 47.07)	21.37 (13.04 to 29.71)	0.003			
Off-task verbal	CON	17.26 (12.32 to 22.20)	15.54 (10.49 to 20.60)	0.577	-7.65 (-16.55 to 1.24)	0.088	-0.3
	B2L	17.57 (12.66 to 22.47)	8.19 (3.13 to 13.25)	0.005			
Off-task motor	CON	6.84 (4.96 to 8.72)	5.74 (3.74 to 7.75)	0.421	-0.58 (-4.42 to 3.27)	0.762	-0.2
	B2L	5.01 (3.15 to 6.87)	3.34 (1.35 to 5.32)	0.217			
Off-task passive	CON	14.04 (9.73 to 18.35)	16.87 (12.43 to 21.30)	0.240	-11.84 (-18.72 to -4.95)	**0.002**	-0.2
	B2L	16.86 (12.58 to 21.14)	7.85 (3.41 to 12.29)	< 0.001			

Note. M = mean, 95% CI = 95% confidence interval, CON = control group, B2L = Burn 2 Learn group

Table 3. *Summary of outcome measures for subjective vitality*

Outcomes	**Group**	**Post-test M (95% CI)**	**Time *p***	**Adj. diff. in change (B2L – CON)**	**Group-by-time p**	**Group-by-time *d***
Start of lesson	CON	3.85 (3.54 to 4.15)				
	B2L	3.93 (3.63 to 4.22)				
End of lesson	CON	3.70 (3.39 to 4.01)				
	B2L	4.49 (4.20 to 4.79)				

Note. M = mean, 95% CI = 95% confidence interval, CON = control group, B2L = Burn 2 Learn group

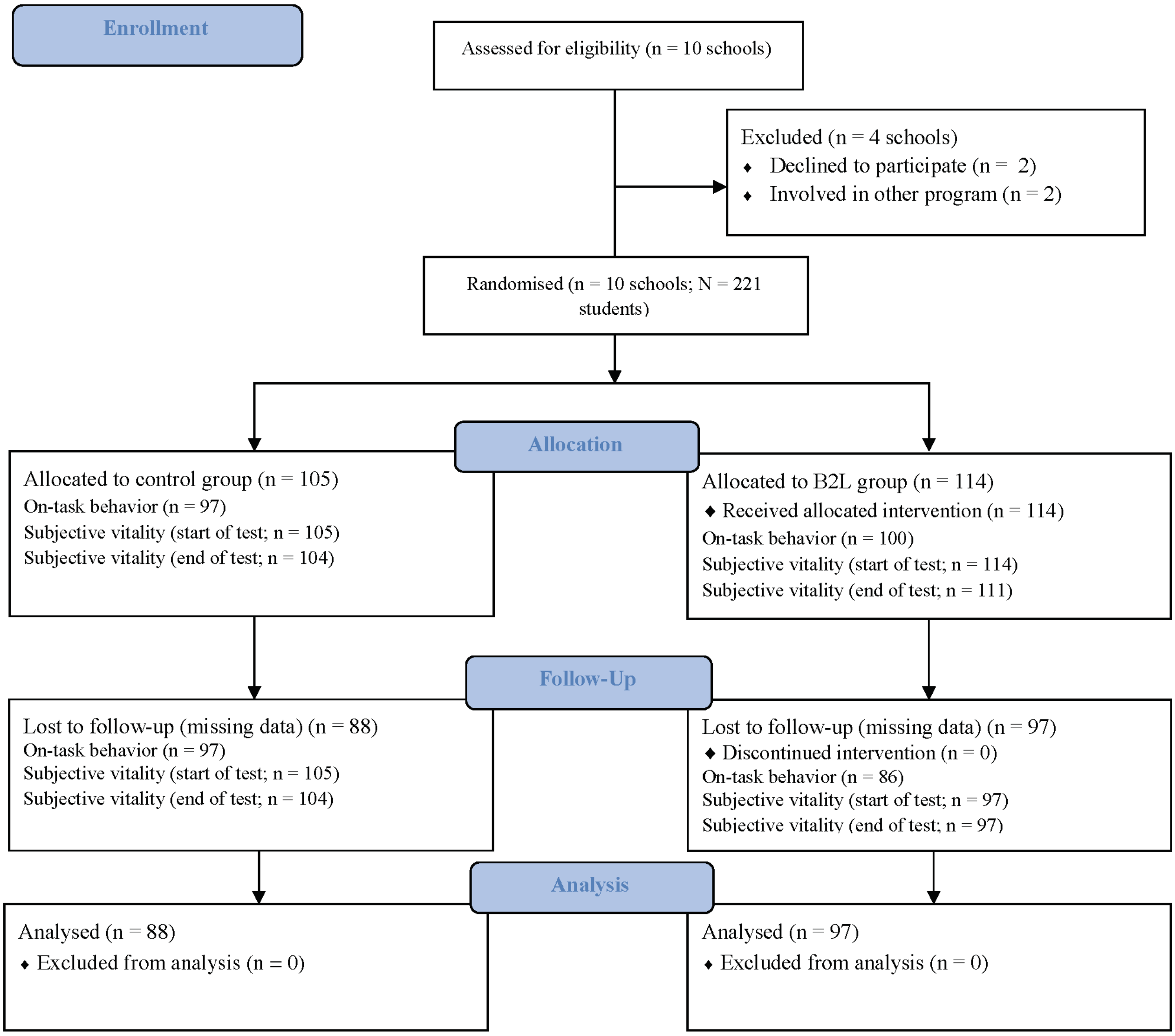

Figure 1. CONSORT 2010 Flow diagram.

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