BMJ Open

A school-based intervention incorporating smartphone technology to improve health-related fitness among adolescents: rationale and study protocol for the NEAT and ATLAS 2.0 cluster randomised controlled trial and dissemination study

David R Lubans,[1] Jordan J Smith,[1] Louisa R Peralta,[2] Ronald C Plotnikoff,[1] Anthony D Okely,[3] Jo Salmon,[4] Narelle Eather,[1] Deborah L Dewar,[1] Sarah Kennedy,[1] Chris Lonsdale,[5] Toni A Hilland,[6] Paul Estabrooks,[7] Tara L Finn,[1] Emma Pollock,[1] Philip J Morgan[1]

To cite: Lubans DR, Smith JJ, Peralta LR, *et al*. A school-based intervention incorporating smartphone technology to improve health-related fitness among adolescents: rationale and study protocol for the NEAT and ATLAS 2.0 cluster randomised controlled trial and dissemination study. *BMJ Open* 2016;**6**:e010448. doi:10.1136/bmjopen-2015-010448

▸ Prepublication history for this paper is available online. To view these files please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2015-010448).

Received 4 November 2015
Revised 14 March 2016
Accepted 18 April 2016

For numbered affiliations see end of article.

Correspondence to
Professor David R Lubans; David.Lubans@newcastle.edu.au

ABSTRACT

Introduction: Physical inactivity has been described as a global pandemic. Interventions aimed at developing skills in lifelong physical activities may provide the foundation for an active lifestyle into adulthood. In general, school-based physical activity interventions targeting adolescents have produced modest results and few have been designed to be 'scaled-up' and disseminated. This study aims to: (1) assess the effectiveness of two physical activity promotion programmes (ie, NEAT and ATLAS) that have been modified for scalability; and (2) evaluate the dissemination of these programmes throughout government funded secondary schools.

Methods and analysis: The study will be conducted in two phases. In the first phase (cluster randomised controlled trial), 16 schools will be randomly allocated to the intervention or a usual care control condition. In the second phase, the Reach, Effectiveness, Adoption, Implementation and Maintenance (Re-AIM) framework will be used to guide the design and evaluation of programme dissemination throughout New South Wales (NSW), Australia. In both phases, teachers will be trained to deliver the NEAT and ATLAS programmes, which will include: (1) interactive student seminars; (2) structured physical activity programmes; (3) lunch-time fitness sessions; and (4) web-based smartphone apps. In the cluster RCT, study outcomes will be assessed at baseline, 6 months (primary end point) and 12-months. Muscular fitness will be the primary outcome and secondary outcomes will include: objectively measured body composition, cardiorespiratory fitness, flexibility, resistance training skill competency, physical activity, self-reported recreational screen-time, sleep, sugar-sweetened beverage and junk food snack consumption, self-esteem and well-being.

Ethics and dissemination: This study has received approval from the University of Newcastle (H-2014-0312) and the NSW Department of Education (SERAP: 2012121) human research ethics committees. This study is funded by the Australian Research Council (FT140100399) and the NSW Department of Education.

Trial registration number: ACTRN12615000360516; Pre-results.

Strengths and limitations of this study

- Strengths of the present study include the randomised controlled trial design, relatively large sample size and use of objective measures of health-related fitness and physical activity.
- In addition, our study will utilise a range of implementation strategies to support intervention fidelity and detailed process data will be collected to help explain study findings.
- Despite these strengths, it is important to acknowledge some limitations. First, the study duration is relatively brief. This decision was made pragmatically, as process data from our previous trials indicated that students and teachers preferred a 10-week programme format.
- Finally, a more direct measure of body composition (ie, DEXA) would have been preferable to the use of body mass index for assessment of this health-related fitness component.

INTRODUCTION

Physical inactivity has been described as a global pandemic with far reaching health, social, economic and environmental implications.[1] Importantly, regular participation in moderate-to-vigorous intensity physical activity (MVPA) is critical for maintaining and improving health-related fitness (ie, body composition, cardiorespiratory fitness, muscular strength and endurance, and flexibility),[2] which is an important predictor of current and future health status.[3 4] Yet, 80% of adolescents worldwide are failing to achieve the amount of physical activity needed to enhance health-related fitness.[5] Of concern, there have been global secular declines in cardiorespiratory[6] and muscular fitness[7–9] among young people, which have coincided with a rise in youth obesity.[10] Although the importance of cardiorespiratory fitness[11] and a healthy body composition[12] have been established for some time, recent evidence has demonstrated the unique health benefits of achieving and maintaining adequate muscular fitness.[13] Consequently, a recommendation to participate in 'muscle strengthening' physical activity (eg, resistance training) now appears in youth physical activity guidelines in a number of countries.[14–17]

Schools are ideally placed to promote health-related fitness and physical activity in adolescent populations, as young people spend 6–7 h per day for 40 weeks of the year in schools, most of which have the facilities, equipment, qualified staff and curriculum to deliver health promotion interventions.[18] Indeed, these settings have the potential to help students meet the recommended 60 min of daily MVPA and develop the knowledge, skills and confidence to be physically active into the future.[18 19] However, schools are less likely to prepare young people for a lifetime of physical activity if their focus remains solely on traditional, competitive team sports and games.[20 21] Such activities may be enjoyable for some and are indeed an effective way for young people to engage in MVPA, particularly for those with the requisite level of skill competency to be successful. However, team sports and games may not have strong carry over effects into adulthood, as many young people drop out of sport during adolescence.[22 23] Moreover, adolescents have identified a desire to try a variety of non-traditional activities, including weight training and fitness classes.[24] Considering the lack of emphasis on alternative physical activities within traditional physical education (PE) and school sport programmes,[20] many young people may leave school ill-equipped to maintain a physically active lifestyle beyond the schooling years.

Lifelong physical activities "are typically performed individually or in small groups, involve minimal structure and minimal physical contact, are characterized by varying levels of intensity and competitiveness, and may be easily carried into adulthood and old age".[21] These activities can contribute substantially to adult physical activity. Indeed, health and fitness activities such as resistance training rank among the most popular sports and physical activities regularly performed by western adults.[25 26] Although these activities are popular in relative terms, the overall prevalence of participation remains quite low. For example, just one in five adults in the USA report 'exercising with equipment'[27] and only 17% of Australian[26] and 14% of English[25] adults regularly engage in 'fitness/gym' and 'health and fitness' activities, respectively. Clearly, for some, health and fitness activities can form an integral part of an active lifestyle during adulthood. However, in addition to common barriers such as time and cost, many adults may feel they lack the competence to participate in these activities effectively.[28 29] Given the capacity for schools to provide students with the skills and confidence to engage in lifelong physical activities,[24] there is a clear rationale for school-based interventions that address adolescents' current and future physical activity needs.

Despite the potential for schools to influence students' health behaviours, previous school-based physical activity interventions have had mixed success and a number of limitations have emerged in the literature.[30 31] First, few interventions have included strategies and components designed to promote muscular fitness, as recommended in national physical activity guidelines. Second, previous interventions have often been developed for 'all' students using a 'one size fits all' approach, regardless of their age and sex. Sex has emerged as a consistent moderator of school-based interventions, suggesting that subgroups such as males and females may benefit from different intervention strategies and sociocultural intervention tailoring.[32 33] Third, previous interventions have often failed to include implementation strategies, which may contribute to poor intervention fidelity and null findings.[34] Finally, the majority of interventions have been evaluated in small-scale efficacy trials and very few have been designed to be 'scaled-up' and disseminated.

Schools can help address the global pandemic of physical inactivity by employing a multicomponent approach that includes quality PE, physical activity within and beyond the school day, staff involvement, as well as family and community engagement.[18 35] Such an approach should include evidence-based programmes that can be implemented within an overall health promotion framework. The Nutrition and Enjoyable Activity for Teen Girls (NEAT)[36–38] and the Active Teen Leaders Avoiding Screen-time (ATLAS)[39 40] programmes were developed specifically to support school-based physical activity promotion and obesity prevention efforts for girls and boys, respectively. The NEAT and ATLAS programmes reduced screen-time[37 40] and improved body composition,[38] muscular fitness,[38 40] resistance training skill competency,[40] and well-being[41] in low-active adolescents. However, similar to other school-based interventions, the original NEAT and ATLAS programmes included a large number of intervention strategies, making them difficult to implement more broadly without the ongoing support of the research team.[42]

Using process evaluation data[40 43] and feedback from the New South Wales (NSW) Department of Education, the programmes were refined to allow for implementation in typical secondary school settings. Therefore, the aims of this two-phased study are to (1) determine the effectiveness of the revised NEAT and ATLAS programmes in 16 schools using a cluster randomised controlled trial (RCT); and (2) evaluate the dissemination of these programmes throughout government-funded secondary schools in NSW, Australia over a 12-month period.

METHODS

Study design

In the first phase of the study, the revised NEAT and ATLAS interventions will be evaluated using a cluster RCT. The intervention will target females and males in year 9 (third year of secondary school) in 16 coeducational, government-funded secondary schools in NSW Australia. Assessments will be conducted at baseline (April/June, 2015) and will be repeated postintervention at 6 months (October/December, 2015) and again at 12-month follow-up (April/June, 2016). Muscular fitness (primary outcome) and other study outcomes will be assessed at baseline, 6 months (primary end point) and 12 months. In addition to these assessments, accelerometer-measured physical activity will be assessed at 3 months (mid-intervention) to determine the effect of the intervention on physical activity during programme implementation. The design, conduct and reporting of this RCT will adhere to the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT)[44] and Consolidated Standards of Reporting Trials (CONSORT) guidelines.[45] Schools will be randomised to the NEAT and ATLAS intervention group or a wait-list control group for the 12-month study period. Schools in the control group will participate in usual practice (ie, regularly scheduled PE and co-curricular school sport) during the study period.

In the second phase of the study, the RE-AIM framework[46 47] will be used to evaluate the dissemination of the interventions (ie, Reach into the student population, Effectiveness in changing student outcomes, Adoption based on teacher training and initiation of program delivery, Implementation fidelity, and Maintenance of student changes and program delivery beyond initial implementation). The research team will develop 'train the trainer' materials to enable dissemination of the NEAT and ATLAS interventions throughout government-funded secondary schools in NSW, Australia. The dissemination phase will not include a control group.

Sample size calculation

Sample size calculations have been based on estimated effect sizes for the primary outcome of muscular fitness assessed using the 90° push-up and standing long jump tests.[48] Although the health benefits of muscular fitness are now well established,[13 49] there is a lack of consensus regarding the clinical significance of changes in muscular fitness in young people. Based on our previous studies, we anticipate an effect size of d=0.4 for muscular fitness (adjusted between-group difference of ∼2 repetitions).[40 50] In accordance with CONSORT guidelines,[45] our power calculations were adjusted for the clustering of effects at the school level. We adjusted for clustering using a correction factor of $[1+(m-1)\times ICC]$, where m=participants per class and ICC=the intraclass correlation coefficient. Assuming an average class size of 20 participating students, two classes per school and an ICC for muscular fitness of 0.09,[40] the correction factor is 2.7 (ie, $1+(^{20}-1)\times 0.09$). Allowing for an expected 10% loss to follow-up at 6 months and a further 10% loss at 12 months, the required sample size to achieve 80% power with α levels set at $p<0.05$ is 640 students from 16 schools (16 intervention classes and 16 control classes). The study will be adequately powered to detect significant between-group differences at the primary study end point (6 months) and at follow-up (12 months).

Setting and participants

The RCT will be conducted within 16 eligible government-funded secondary schools located within the Hunter, Central Coast and Sydney regions of NSW. To identify eligible schools, our research team will use the NSW Department of Education website 'School Locator' function to identify Government secondary schools within approximately 50 km of the University of Newcastle and the University of Sydney. Eligible participants will be adolescent males and females in year 9 attending 1 of the 16 recruited schools who do not have an injury or illness that would affect participation in a physical activity and resistance training programme. The programmes will be implemented within schools by members of the teaching staff at each school, who may be PE teachers or teachers of other subject areas. Female and male teachers will facilitate the NEAT and ATLAS programmes, respectively.

In the dissemination phase, all secondary schools in NSW will be eligible to participate and the programme will be open to students in years 9 and 10. The dissemination of the NEAT and ATLAS programmes will begin in October, 2015 (as requested by the department of education) and continue until October 2017. During this phase, the research team will aim to deliver two professional learning workshops per school term, resulting in a total of 16 workshops over the dissemination period. Overall, the research team will aim to recruit and train 240 teachers (ie, 15 teachers per workshop) to deliver the NEAT and/or ATLAS programmes in their schools.

Blinding and randomisation

In the cluster RCT, recruitment and baseline data collection will be conducted prior to randomisation, thereby concealing group allocation, and attempts will be made to blind research assistants to group allocation at the postintervention and follow-up time points (however, this is not always possible in school-based cluster RCTs). Following baseline data collection, schools will be match-paired based on size, geographical location and socio-economic status (SES). Schools within each pair will then be randomised to either the intervention group or the wait-list control group by a researcher not involved in the current study using a computer-based random number producing algorithm. As such, schools randomised to the intervention condition will deliver both the ATLAS and NEAT programmes during the study period, whereas schools in the control condition will not deliver either programme until the completion of the 12-month study assessments. In the dissemination phase there will be no control group.

Intervention

Following the research evaluation of the NEAT[36–38] and ATLAS[39 40] programmes, the lead investigator was approached by the NSW Department of Education to develop a sustainable intervention model that could be disseminated across secondary schools in NSW. The Department of Education determined that the original NEAT and ATLAS programmes were too intensive and not sustainable without the support of the research team. Feedback from the Department of Education and examination of process evaluation data were used to guide the modification of intervention strategies. The following changes were made: (1) increased focus on resistance training (NEAT and ATLAS); (2) removal of nutrition workshops (NEAT), as these were considered too expensive and resource intensive; (3) removal of parent newsletters (NEAT/ATLAS) because they were not read extensively by parents/care givers; (4) text messaging strategy replaced with smartphone app (NEAT) to minimise cost; (5) removal of pedometer component (NEAT/ATLAS), as participant usage was low in NEAT and ATLAS; and (6) structured physical activity programme duration reduced to 10 weeks (NEAT/ATLAS) from 40 weeks (NEAT) and 20 weeks (ATLAS) to fit within one school term.

A summary of the revised NEAT and ATLAS implementation strategies and four gender-targeted intervention components is provided in figure 1. The following evidence-based implementation strategies will be used to ensure that the intervention is delivered as intended:[51] (1) recruitment of school champions; (2) professional learning workshop for teachers; (3) provision of teacher handbook, session resources and fitness equipment; and (4) physical activity session observation and feedback. The intervention consists of the following components: (1) interactive student seminar; (2) structured physical activity programme; (3) lunch-time fitness sessions; and (4) web-based smartphone apps (separate apps for ATLAS and NEAT). Gender-targeted versions of the four intervention components were developed for girls (NEAT) and boys (ATLAS). A detailed description of the implementation strategies and intervention components for the NEAT and ATLAS programmes that will be delivered in the RCT and dissemination phases are provided in table 1.

The NEAT and ATLAS interventions were guided by Social Cognitive Theory (SCT)[52] and Self-Determination Theory (SDT).[53] More specifically, the intervention was informed by the transcontextual model of motivation,[54] which postulates that enhancing motivation for physical activity in one context (eg, PE) will promote motivation for physical activity in other contexts (eg, after school and on weekends).[55] SDT has emerged as a popular and useful theoretical framework for modifying PE teachers' pedagogies and increasing adolescents' motivation for PE.[56–59] In the current study, the teacher professional learning workshop will be used to provide teachers with strategies to satisfy students' basic psychological needs for autonomy (ie, sense of choice and volitional control), competence (ie, sense of mastery) and relatedness (ie, social connection with the teacher and fellow students).[53] SDT will be operationalised using the 'SAAFE' (Supportive, Active, Autonomous, Fair and Enjoyable) teaching principles,[60] which will be explained to teachers and reinforced using lesson observations and feedback. Consistent with SDT,[53] satisfying these basic psychological needs should promote autonomous motivation for participating in health-related fitness activities. In regards to SCT, teachers will learn strategies for enhancing students' self-efficacy in resistance training and other health-related fitness activities (eg, providing encouragement, giving specific feedback on technique, modelling correct performance) and students will learn important behavioural skills such as physical activity self-monitoring and goal setting. These behavioural skills will be taught in the interactive seminar and embedded within the NEAT and ATLAS web-based apps.

The NEAT and ATLAS interventions include five evidence-based physical activity and nutrition messages, modified from the original interventions: (1) Move whenever you can; (2) Get some vigorous physical activity on most days; (3) Limit your recreational screen-time; (4) Avoid sugary drinks; and (5) Limit 'sometimes' foods. Although the messages are consistent for both adolescent girls (NEAT) and boys (ATLAS), they have been operationalised using a gender-targeted approach to enhance their relevance and salience. A range of sociocultural targeting strategies (surface and deep)[33 62] were used to ensure that the NEAT and ATLAS interventions were appropriate for adolescent girls and boys (table 2). For example, the circuit cards and intervention resources featured pictures of young females (NEAT) and males (ATLAS). In addition, the content of the interactive seminars was designed to be relevant to boys and girls by recognising and focusing on established gender differences in specific health behaviours and motivational profiles. For example, research has shown that video gaming is typically a greater contributor to recreational screen-time for boys compared

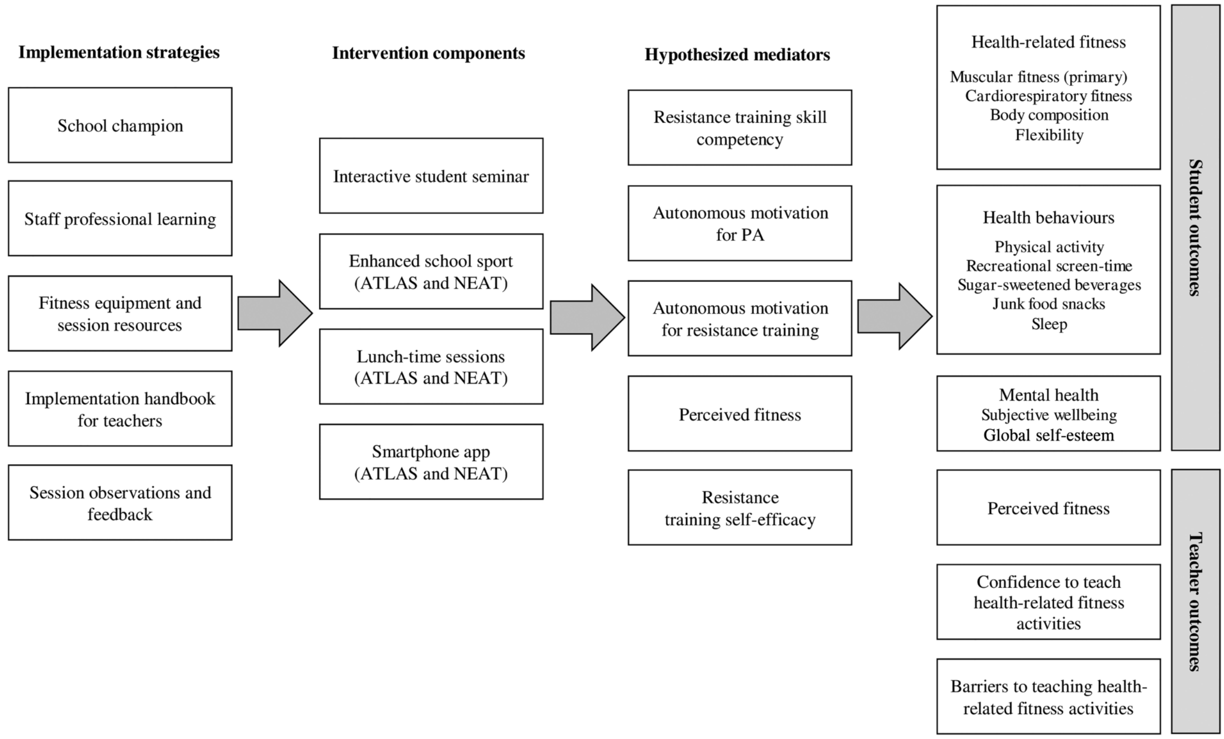

Figure 1 Implementation strategies, intervention components, hypothesised mediators and study outcomes. ATLAS, Active Teen Leaders Avoiding Screen-time; NEAT, Nutrition and Enjoyable Activity for Teens; PA, physical activity.

with girls, who tend to spend more time using social media.[63]

Study measures

In the cluster RCT, baseline, postintervention and follow-up assessments will be conducted by experienced research assistants and undergraduate student volunteers with a background in kinesiology or PE. To ensure consistency between assessors, a protocols booklet containing the instructions for each test was developed and will be used at all data collection periods. Prior to baseline, all assessors will attend a 2 h training workshop to familiarise them with the testing protocols. In the dissemination phase, the intensity of evaluation has been reduced due to the larger number and more distant schools that may participate.

Primary outcome (student)

Muscular fitness

Testing procedures and a demonstration from the assessor will be provided to participants prior to the conduct of the tests. Upper body muscular endurance will be assessed using the 90° push-up test.[64] Consistent with the training principle of 'specificity', adaptions resulting from exercise will be specific to the type of training that is completed. As push-ups closely mirror one of the body weight exercises that will be delivered, this test is considered appropriate for evaluating changes in muscular fitness resulting from the intervention. In addition, this is a feasible field-based test that schools can use to evaluate programme effectiveness in the future, without the need for support from the research team. Using a cadence of 40 bpm (ie, one push-up every 3 s) participants lower themselves in a controlled manner from the start position until a 90° angle is formed at the elbow then push back up. The test concludes when participants either fail to maintain the movement with adequate form, fail to lower themselves to the required depth on three non-consecutive repetitions or on volitional failure. This test has acceptable test-retest reliability in adolescents (ICC (95% CI)=0.90 (0.80 to 0.95)).[65] Lower body muscular strength will be assessed using the standing long jump test.[66] Participants will begin with their toes behind a line marked at 0 cm and perform a maximal long jump, taking off and landing with two feet. The test will be performed twice, separated by a rest period of at least 15 s. The jump distance (in cm) will be recorded in line with the heel of the rearmost foot, with the longer of the two jumps recorded as the participant's final score. This test has been shown to be a valid and reliable method for assessing adolescents' lower body muscular strength.[67]

Secondary outcomes (student)

Body mass index

Height will be recorded using a portable stadiometer (Model no. PE087, Mentone Educational Centre, Australia) and weight will be measured using a portable digital scale (Model no. UC-321PC, A&D Company Ltd, Tokyo Japan). Body mass index (BMI) will be calculated using the standard equation (weight [kg]/height[m]^2). Weight status will be determined according to age-

Table 1 Description and dose of implementation strategies and intervention components

Strategy/component	Dose	Description
Implementation strategies		
1. School champions	*RCT:* 2× teachers/school *Dissemination:* 2× teachers/school	In both the RCT and dissemination phases, 2 school champions from each school will be identified and recruited to act as organisers at each of the study schools. These teachers will liaise with the research team to recruit students, organise study assessments. In the dissemination phase, if only 1 teacher from a school participates in the professional learning workshop, only 1 school champion will be recruited.
2. Professional learning workshop for teachers	*RCT:* 1× workshop (preprogramme) *Dissemination:* 1× workshop (preprogramme)	Teachers will be invited to attend a 1 day professional development workshop in the RCT phase. Professional learning will be provided for two PE and two non-PE teachers (2 male and 2 female) from each intervention school in the RCT. As an incentive for participation, the teacher workshop will be certified with the Board of Studies, Teaching and Educational Standards (BOSTES), the professional body responsible for teacher certification and professional learning accreditation within the NSW Government schooling system. The workshop will address all aspects of NEAT and ATLAS interventions including: (1) teacher roles and expectations; (2) intervention components; (3) introduction to RT and safety implications; and (4) philosophy of the programmes, including the gender-targeting strategies and explanation of the 'SAAFE' teaching principles.[60] In the dissemination phase, NSW Department of Education staff members will be trained to deliver the workshop and 2 teachers (1 male and 1 female) from each school will be invited to participate. However, schools may still participate in the dissemination phase if only 1 teacher attends the professional learning workshop.
3. Implementation handbook, fitness equipment and session resources	*RCT:* 2× each school *Dissemination:* 2× each school (no fitness equipment except on request)	In the RCT phase, each school will be provided with two facilitator handbooks, two sets of 67 exercise circuit cards and two fitness equipment packs. Valued at ~$1500 AUD each, the equipment packs will each include: 15 Gymstick resistance band devices, 5× skipping ropes, 5× sets of boxing gloves and focus pads, 2× agility ladders, and 1× suspension strap. In the dissemination phase, each school will be provided with the facilitator handbooks and exercise circuit cards only. However, basic fitness equipment packs worth $300 AUD (including 5 Gymstick resistance band devices), will be provided by the NSW Department of Education School Sport Unit on request.
4. Session observation and feedback	*RCT:* 4× each school *Dissemination*: 1× teacher	In the RCT phase, the research team will observe two NEAT and ATLAS sessions at each intervention school using a structured observation checklist. The checklist will be used to assess intervention fidelity and provide feedback to teachers. Fidelity will be assessed as compliance with the proposed session structure: (1) warm-up; (2) RT skill development; (3) 7 min High Intensity Resistance Training workout; (4) student choice of boxing circuit, Yoga/Pilates activity, or modified ball game; (5) Cool down. Using this checklist, supportive and motivational feedback will also be given to teachers regarding their application of the SAAFE teaching principles during session delivery.[60]

Continued

Table 1 Continued

Strategy/component	Dose	Description
Intervention components	*RCT and dissemination*	
1. Student interactive seminar	1× 30 min (week 1)	The seminar will be delivered by teachers and provide key information regarding the programme components and behavioural messages, including current recommendations for youth physical activity, screen-time, resistance training and nutrition. It will also provide an overview of the smartphone app functions. The student seminar has been designed to be engaging with the integration of videos and websites, student quizzes and opportunities for student input and discussion.
2. Structured physical activity sessions	10× ~90 min (weeks 1–10)	Sessions will be delivered by trained teachers at the study schools and will follow a uniform structure previously designed by the research team. Activities will include bodyweight and elastic tubing resistance training, flexibility-based, aerobic-based and strength-based activities, high-intensity fitness challenges and modified ball games. Behavioural messages will be reinforced by teachers throughout the sessions.
3. Lunch-time fitness sessions	5×20 min (weeks 6–10)	Students will participate in self-directed workouts during lunch-time and will be provided with opportunities to demonstrate leadership skills by organising and running these sessions under the supervision of teachers. Teachers will be asked to facilitate a minimum of 5 lunch-time sessions over the 10-week intervention period, but will be encouraged to facilitate additional lunch-time sessions if possible.
4. Web-based smartphone app	1× ATLAS app 1× NEAT app (weeks 1–10)	The NEAT and ATLAS apps will be available on iOS, Android and Windows platforms, and are also compatible for use on a personal computer. The apps include: (1) an exercise library including GIF animated images and descriptions of exercises; (2) descriptions of 7 min high intensity resistance training workouts of varying intensities with built-in count-down timer and option for entering individual results; (3) self-monitoring function for recording and reviewing physical activity; (4) tailored motivational messaging via twice-weekly emails to reinforce the five behavioural messages; (5) goal setting to promote participation in MVPA; and (6) the Resistance Training Skills Battery[61] checklist for evaluating and improving resistance training movement skill competency.

ATLAS, Active Teen Leaders Avoiding Screen-time; AUD, Australian dollars; MVPA, moderate-to-vigorous intensity physical activity; NEAT, Nutrition and Enjoyable Activity for Teens; NSW, New South Wales; PE, physical education; RCT, randomised controlled trial; SAAFE, Supportive, Active, Autonomous, Fair and Enjoyable.

Table 2 Sociocultural targeting strategies used in the NEAT and ATLAS cluster RCT

Programme components	Socio-cultural targeting strategies to engage adolescent girls and boys
Recruitment	▸ Presentation of programme to students from same-sex role model (ie, delivered by PE or non-PE teacher) (NEAT/ATLAS). ▸ Recruitment flyer depicts adolescent males performing exercises and targets valued outcomes for boys (eg, "Boys, would you like to work out with your mates and become fitter, stronger and more active?") (ATLAS). ▸ Recruitment flyer depicts adolescent females performing exercises and targets valued outcomes for girls (eg, "Girls, do you want to improve your health and fitness and have fun with your friends in a supportive environment?") (NEAT). ▸ Focused on resistance training to develop strength and fitness in a male-only environment (ATLAS). ▸ Focus on enjoyable and non-competitive lifelong activities (eg, Yoga) in a female-only environment (NEAT).
Content	▸ Programme logo depicts same-sex individuals performing exercises (NEAT/ATLAS). ▸ Branding of programme components to engage participants (eg, GymFit is the resistance training component and is branded to engage girls. Yoga and Pilates style exercise is branded as CoreFit to engage boys) (NEAT/ATLAS). ▸ Programme resources (eg, circuit cards, smartphone app) include images of same-sex role model (NEAT/ATLAS). ▸ Separate smartphone apps for boys and girls with same functionality but different colour scheme (NEAT/ATLAS). ▸ Names of the predesigned workouts designed to appeal to girls (e.g., '*Fit and Fabulous*') and boys (eg, '*Annihilator*') (NEAT/ATLAS). ▸ 'Tailored' emails sent via smartphone app target health behaviours specific to each sex. For example, video gaming for boys and social media use for girls. Messages use language identifying target group (eg, "Did u know that teenage girls should be active for 60 min each day to maintain good health?") (NEAT/ATLAS). ▸ Separate interactive seminars designed for girls and boys focusing on health behaviours common to each sex (eg, excessive video gaming for boys, skipping breakfast for girls), sex-specific barriers to physical activity participation (eg, beliefs that girls shouldn't get sweaty), and use of language identifying target group (eg, "Did you know that boys typically become less active as they get older") (NEAT/ATLAS).
Format	▸ Delivered at school during scheduled PE or school sport period in single-sex groups (NEAT/ATLAS). ▸ Use of smartphone apps for self-monitoring, goal setting, fitness and skill self-assessment (NEAT/ATLAS). ▸ Focus on autonomy and self-direction in practical sessions (NEAT/ATLAS).
Facilitator	▸ Same-sex teacher delivering programme to students (NEAT/ATLAS). ▸ Professional learning for teachers includes information on how to adapt behavioural messages to be more relatable and meaningful for boys and girls by focusing on familiar behaviours and valued outcomes (NEAT/ATLAS).
Pedagogy	▸ Autonomy supportive strategies embedded within programme to allow boys and girls to select activities that appeal to them (NEAT/ATLAS). ▸ Researcher observations and feedback to teachers to provide advice on how to increase the relevance and salience of behavioural messages to students and how to apply the SAAFE teaching principles (NEAT/ATLAS).

ATLAS, Active Teen Leaders Avoiding Screen-time; NEAT, Nutrition and Enjoyable Activity for Teens; NSW, New South Wales; PE, physical education; RCT, randomised controlled trial.

specific and sex-specific BMI z-scores using the lambda-mu-sigma (LMS) method (International Obesity Task Force cut-offs).[68]

Cardiorespiratory fitness

Maximal aerobic capacity (ie, VO_2 max) will be estimated using a submaximal step test protocol.[69] Participants will be fitted with a heart rate monitor and asked to step up and down on a portable step (step height adjusted according to sex and standing height) for 3 min at a cadence of 88 bpm (ie, 22 ascents per minute). After 3 min, participants will be asked to stand still while their heart rate is recorded at 5, 10 and 15 s intervals. Recovery heart rate at 15 s will be calculated as the difference between the 15 and 5 s heart rate readings. Estimated VO_2 max in mL/kg/min will be calculated using the regression equation reported by Francis and Feinstein.[69] Using this approach, Francis and

Feinstein reported a correlation coefficient of r=0.81 between estimated and actual VO_2 max among a sample of 6–18-year-old youth.

Flexibility

Flexibility will be assessed using the FITNESSGRAM back-saver sit and reach test.[64] Participants remove their shoes and sit with one leg extended against a portable trunk flexibility tester (Model no. PEO41, Sportime Ltd, Wisconsin, USA). Participants will be asked to extend forward as far as possible in a smooth and controlled manner whilst keeping the extended leg straight, head upright and palms facing downwards with fingers aligned. Participants will be instructed to gently push the measuring guide forward, pausing momentarily at the endpoint of the stretch. The measurement will be taken to the nearest 0.5 cm in line with the measurement guide and the test will then be repeated with the opposite leg extended.

Resistance training skill competency

Resistance training skill competency will be assessed using video analysis of the Resistance Training Skills Battery (RTSB).[61 70] The RTSB includes six foundational RT movements completed in the following order: squat, push-up, lunge, overhead press (completed with 2 kg bar), front-support with chest touches, and suspended row. Each movement skill is performed twice (ie, two sets) for four repetitions and is scored by adding the total number of performance criteria (either four or five) successfully demonstrated during each set. The resulting skill score is therefore out of a possible 8 or 10, depending on the skill. An overall resistance training skill quotient is calculated by summing each of the six skill scores (possible range 0–56). Participants complete each exercise after viewing a standardised video demonstration of the skill pre-recorded on Apple iPads. The RTSB has demonstrated satisfactory construct validity, test-retest reliability (ICC (95% CI)=0.88 (0.80 to 0.93)),[61] and interrater reliability[70] in a sample of adolescents.

Physical activity

Stratified by school, a random subsample (50%) of students will wear GENEActiv wrist-worn accelerometers (Model GAT04, Activinsights Ltd, Cambridgeshire England). Participants will be instructed to wear the accelerometer continuously for seven consecutive days (even while sleeping, bathing and swimming). Valid wear-time will be classified as at least 10 h of data on at least 3 days. Mean weekday and weekend day MVPA will be determined using previously developed thresholds[71] to classify physical activity into sedentary, light, moderate and vigorous intensity. In addition, all participants will be asked to self-report their total physical activity and participation in muscle strengthening physical activity using a validated measure.[72 73]

Recreational screen-time

A modified version of the Adolescent Sedentary Activity Questionnaire (ASAQ)[39 74] will be used to determine time spent in screen-based recreation. The modified ASAQ addresses the issue of screen-multitasking[75] by asking participants to report for each day of the week the ‘total time’ spent sitting using screens (of any kind) for the purposes of entertainment.

Sleep time and sleep quality

Sleep time and sleep quality will be assessed using items from the School Sleep Habits survey.[76] Students will be asked to reflect on the past two weeks and report the ‘usual’ time they went to bed and the time they woke up on ‘school days’ and ‘weekends’ separately. School day and weekend day sleep onset latency (ie, the time taken to get to sleep) will be also assessed, with total sleep time calculated by subtracting the sleep onset latency from the total time between going to bed and waking. In addition, two items will be used to evaluate the quality of students’ sleep (eg, How often do you think that you get enough sleep?). The Sleep Habits Survey has previously been validated against sleep diary report and actigraphy among adolescents.[77]

Sugar-sweetened beverage and junk food snack consumption

Two items from the NSW Schools Physical Activity and Nutrition Survey (SPANS)[78] will be used to assess participants’ regular intake of sugar-sweetened beverages (SSB’s), which include fruit-based beverages (eg, orange juice), cordials, energy drinks and soft drinks (ie, soda). Consumption of junk food snacks (eg, biscuits, ice cream, cakes) will be assessed using a single item from the previously validated Australian Child and Adolescent Eating Survey.[79]

Global self-esteem

A five-item subscale from the Physical Self-Description Questionnaire (PSDQ) (short form)[80] will be used to assess self-esteem. Students respond on a six-point scale (1=false, to 6=true) to how true each statement is for them (eg, overall, I have a lot to be proud of). The PSDQ has been validated previously.[80]

Psychological well-being

Diener *et al*[81] psychological flourishing scale will be used to measure subjective well-being. Using a seven-point scale (1=strongly disagree, to 7=strongly agree), students respond to statements relating to indicators of ‘eudemonic’ well-being (eg, I lead a purposeful and meaningful life). Items in the scale are summed to create a composite well-being score (possible range 8–56). The validity of the measure has been established previously.[81]

Hypothesised mediators (student)

Autonomous motivation for physical activity

Autonomous motivation for physical activity will be assessed using the intrinsic and identified subscales from the Behavioural Regulations in Exercise Questionnaire-2 (BREQ-2).[82] Students respond on a five-point scale to how true each statement is for them (1=Not true for me, to 5=Very true for me). Items are adapted to reflect participation in 'physical activity' rather than exercise specifically (eg, I value the benefits of physical activity). The factorial validity of the measure has been established previously.[82]

Motivation to participate in resistance training

To evaluate motivation for RT, an adapted version of the complete BREQ-2 will be used.[82] Items are adapted to reflect participation specifically in resistance training (eg, I value the benefits of resistance training), rather than exercise more broadly. The complete BREQ-2 includes 19 items and five subscales corresponding to the motivational regulations outlined in SDT (ie, intrinsic motivation, identified regulation, introjected regulation, external regulation, and amotivation).

Perceived fitness

Perceived physical fitness will be self-reported using the International Fitness Scale (IFIS).[83] The IFIS is a five-item instrument in which participants report perceptions of their 'general fitness' and four other specific fitness components (*1=very poor, to 5=very good*). The validity and test-retest reliability of the IFIS has been found to be acceptable among a sample of 9–12 year old youth.[83] The IFIS will also be used to evaluate perceived fitness among participating teachers.

Resistance training self-efficacy

Self-efficacy for resistance training will be assessed using a four-item scale developed for use with adolescents.[65] Participants report their agreement to each statement (eg, I have the skill and technique to complete resistance training exercises safely) using a five-point Likert scale (1=Strongly disagree, to 5=Strongly agree). Test-retest reliability for this scale has been found to be good (ICC (95% CI)=0.81 (0.64 to 0.90)).[65]

Secondary outcomes (teacher)

Confidence to teach health-related fitness activities

Teacher confidence to deliver health-related fitness activities will be assessed using an adapted version of an existing scale.[84] The original items applied to a variety of learning activities which are typically taught as part of the PE curriculum. For the present study, the items are adapted to apply only to the teaching of health-related fitness activities.

Barriers to teaching health-related fitness activities

Perceived barriers to teaching health-related fitness activities will be evaluated using items adapted from an existing scale, originally applied to delivering the Health and PE curriculum.[85] The adapted scale includes many of the same barriers as the original, but focuses instead on the delivery of health-related fitness activities. Additional barriers relevant for health-related fitness activities (eg, litigation concerns) were added to the scale and teachers can add barriers that are not already listed. Teachers respond to each potential barrier using a six-point scale (1=No barrier or does not inhibit, to 6=A major barrier or strongly inhibits).

Process evaluation

A process evaluation will be conducted to determine intervention fidelity and programme acceptability for the RCT and dissemination phases. Process measures will include: (1) teacher attendance and satisfaction with the professional learning workshop (workshop evaluation questionnaires); (2) number of NEAT/ATLAS physical activity sessions delivered (teacher logs and session observations); (3) student participation in the interactive seminars and lunch-time sessions (teacher logs); (4) student engagement with the web-based app (objective usage data); (5) NEAT/ATLAS session fidelity via observations (2 per teacher in RCT and 1 per teacher in dissemination phase); and (6) overall teacher and student satisfaction with the NEAT/ATLAS programmes (process evaluation questionnaire).

RE-AIM[46] will provide a framework for the process evaluation of the NEAT and ATLAS interventions during the dissemination phase of the study. As shown in table 3, the RE-AIM framework will be applied to evaluate the interventions at both the organisational and individual levels. RE-AIM[47] was operationalised as follows: (1) reach (individual level)—the absolute number, proportion and representativeness of students who participate in the NEAT/ATLAS interventions compared with those who declined and students' attendance at sessions and engagement with web-based app; (2) effectiveness (individual level)—the impact of the NEAT/ATLAS programmes on student health outcomes and behaviours; (3) Adoption (setting level)—the absolute number, proportion and representativeness of schools and teachers who are willing to deliver the NEAT/ATLAS programmes and the impact of the professional learning workshops on teacher outcomes; (4) Implementation (setting level)—the fidelity of the NEAT/ATLAS programmes delivered in schools; (5) Maintenance (setting and individual levels)—the long-term effects of the NEAT/ATLAS programmes on student health outcomes and behaviours, and the extent to which the NEAT/ATLAS programmes have become routine organisational practices within recruited schools.

Statistical analysis

Statistical analyses of the primary and secondary outcomes in the RCT phase will be conducted using linear mixed models in IBM SPSS Statistics for Windows, V.20.0 (2010 SPSS Inc., IBM Company Armonk, New York,

Table 3 Application of the RE-AIM framework to evaluate the dissemination of the NEAT and ATLAS interventions

Dimension	Level of analysis/measures	Measure detail	Data sources	Time point
Reach	*Individual*			
	Number, proportion and representativeness of students who participate.	Number of the students that participate in the NEAT/ATLAS programmes compared to total number of students at participating schools.	Individual school enrolment data My school website http://www.myschool.edu.au/	On-going
		Age, sex, indigenous status, SES, ethnicity/cultural background, locality, language spoken at home of students who participate in the NEAT/ATLAS programmes compared to others in the school.	Self-reported demographic information.	Baseline
	Student participation rates.	Number of NEAT/ATLAS sessions completed by students.	Register completed by teachers.	On-going
	Student engagement with smartphone apps.	Number of workouts logged, number of goals recorded, completion of RT movement skill analysis, frequency and duration of app usage.	App usage data from administration site.	On-going
Effectiveness				
	Individual			
	Impact of intervention on student outcomes.	Self-reported PA, perceived fitness, resistance training self-efficacy, subjective well-being, recreational screen-time, autonomous motivation for PA, autonomous motivation for RT, junk food snack consumption, SSB consumption.	Self-reported PA,[72] self-reported participation in resistance training,[73] IFIS,[83] resistance training self-efficacy scale,[65] Diener's psychological flourishing scale,[81] ASAQ,[74] BREQ-2,[82] modified BREQ-2,[82] ACAES,[79] SPANS.[78]	Baseline, 10 weeks
	Student evaluation of intervention	Student satisfaction with programme	Process evaluation questionnaire	10 weeks
Adoption	*Organisational*			
	Programme delivery.	Total number of NEAT/ATLAS programmes delivered at each school.	Register completed by schools, details recorded by researchers.	Ongoing
	Impact of intervention on teacher outcomes.	Perceived fitness, confidence to teach health-related fitness activities, barriers to teaching health-related fitness activities.	IFIS,[83] confidence to teach health-related fitness activities,[84] barriers to teaching health-related fitness activities.[85]	Baseline, 10 weeks
	Teacher evaluation of intervention.	Teacher satisfaction with programme.	Process evaluation questionnaire.	10 weeks
Adoption	*Organisational*			
	Number, proportion and representativeness of schools that participate in the professional learning workshops.	Number of schools represented by teachers at the professional learning workshops. Proportion of Indigenous students, school type (e.g., SSPs, Co-Ed vs single-sex), school size, proportion of ESL students, SEIFA value, geographic location, school facilities compared to other schools in NSW.	SEIFA, MySchools website, NSW DEC database, interview data.	Baseline

Continued

Table 3 Continued

Dimension	Level of analysis/measures	Measure detail	Data sources	Time point
	Number, proportion and representativeness of teachers that participate.	Number of teachers recruited and attending professional learning workshop. Teacher subject specialty, teacher age and sex, years of teaching experience, perceived fitness, confidence to teach health-related fitness activities, and perceived barriers to teaching health-related fitness activities.	Attendance at professional learning workshop. Self-reported demographic information, IFIS,[83] confidence to teach health-related fitness activities,[84] and barriers to teaching health-related fitness activities.[85]	Baseline
Implementation	*Organisational* NEAT/ATLAS overall programme fidelity.	Delivery of student interactive seminar by teachers, number of prescribed NEAT/ATLAS sessions delivered, number of postsession teacher self-evaluations completed.	Attendance register; details recorded by researchers, process evaluation questionnaire.	On-going
	NEAT/ATLAS practical session fidelity.	Peer observation of NEAT/ATLAS session (teacher-led).	Fidelity assessment and feedback on delivery (teacher-led) using SAAFE teaching principles checklist.[60]	Weeks 3–6
Maintenance	*Organisational* Integration of NEAT/ATLAS into usual practice.	Proportion of schools continuing to deliver NEAT/ATLAS programmes after initial implementation (after initial 10-week programme).	Correspondence with recruited schools; details recorded by researchers.	20 weeks
	Maintenance of intervention effects for teachers.	Perceived fitness, confidence to teach health-related fitness activities, barriers to teaching health-related fitness activities.	IFIS,[83] confidence to teach health-related fitness activities,[84] barriers to teaching health-related fitness activities.[85]	20 weeks
	Individual Maintenance of intervention effects for students.	Self-reported PA, perceived fitness, RT self-efficacy, subjective well-being, recreational screen-time, autonomous motivation for PA, autonomous motivation for resistance training, junk food snack consumption, SSB consumption.	Self-reported PA,[72] self-reported participation in resistance training,[73] IFIS,[83] resistance training self-efficacy scale,[65] Diener's psychological flourishing scale,[81] ASAQ,[74] BREQ-2,[82] modified BREQ-2,[82] ACAES,[79] SPANS.[78]	20 weeks

ACAES, Australian Child and Adolescent Eating Survey; ASAQ, Adolescent Sedentary Activity Questionnaire; ATLAS, Active Teen Leaders Avoiding Screen-time; BREQ-2, Behavioural Regulations in Exercise Questionnaire—version 2; DEC, Department of Education and Communities; ESL, English as a second language; IFIS, International Fitness Scale; NEAT, Nutrition and Enjoyable Activity for Teens; NSW, New South Wales; PA, physical activity; RE-AIM, Reach, Effectiveness, Adoption, Implementation and Maintenance; SAAFE, Supportive, Active, Autonomous, Fair, Enjoyable; SEIFA, Socio-Economic Indexes For Areas; SES, socioeconomic status; SPANS, School Physical Activity And Nutrition Survey; SSB, sugar-sweetened beverage; SSP, schools for specific purposes.

USA), with α levels set at $p<0.05$. The models will be used to assess the impact of treatment (intervention or control), time (treated as categorical with levels baseline, 6 and 12 months) and the group-by-time interaction, using random effects to account for the clustered nature of the data. Although randomisation will occur at the school level, our statistical analyses will be adjusted for the clustering of effects at the class level. This is because our intervention will be delivered to students in classes and school-based studies have demonstrated that clustering at the school level is negligible after accounting from clustering at the class level.[59 86] Mixed model analyses are consistent with the intention-to-treat principle, assuming the data are missing at random. The validity of this assumption will be explored by assessing relationships between missing and observed values of covariates and previous outcomes. Multiple imputation and/or pattern mixture modelling will be considered as a sensitivity analysis if the dropout rate is substantial. Three potential moderators (ie, sex, household SES, and initial weight status) will be explored using linear mixed models with interaction terms and subgroup analyses will be conducted if $p<0.1$.[87] Hypothesised mediators of physical activity and sedentary behaviour change will be examined using multilevel linear analysis and a product-of-coefficients test that is appropriate for cluster RCTs. In the dissemination phase, within group changes will be explored using mixed models and descriptive statistics will be reported.

ETHICS AND DISSEMINATION

Ethics approval for RCT and dissemination phases was obtained from the Human Research Ethics Committee of the University of Newcastle, Australia (H-2014-0312) and the NSW Department of Education and Communities (SERAP: 2012121). School Principals, teachers, parents and students all provided informed written consent prior to enrolment. It is not expected that participants will be at any greater risk of adverse events than they would be when participating in other types of school-based physical activity. However, the teacher handbook includes a section for teachers to report any injuries or adverse events that may occur. Any amendments to the study protocols will be publicly available via the Australian and New Zealand Clinical Trials Registry (Trial number: ACTRN12615000360516). Data management procedures will be conducted by DRL and JS. All entered data will be de-identified using participant codes and will be stored electronically in a password protected drive at the University of Newcastle. Quality checks of entered data will be completed by JS (ie, range checks). Access to the final trial dataset will comply with the conditions of the ethics committee approval and will be at the discretion of the lead CI, DRL. The findings of the RCT and dissemination studies will be published in peer-reviewed journals and all participating schools in the RCT will receive a report outlining the study findings at the conclusion of the trial.

Author affiliations
[1]Priority Research Centre for Physical Activity and Nutrition, School of Education, University of Newcastle, Callaghan, New South Wales, Australia
[2]Faculty of Education and Social work, University of Sydney, Sydney, New South Wales, Australia
[3]Early Start Research Institute, School of Education, University of Wollongong, Wollongong, New South Wales, Australia
[4]School of Exercise and Nutrition Sciences, Deakin University, Burwood, Victoria, Australia
[5]Faculty of Health Sciences, Institute for Positive Psychology and Education, Australian Catholic University, Strathfield, New South Wales, Australia
[6]Faculty of Education, Monash University, Clayton, Victoria, Australia
[7]Department of Human Nutrition, Foods and Exercise, Virginia Polytechnic Institute, Blacksburgh, Virginia, USA

Contributors All authors contributed intellectually to the study design and research methodology, or will be directly involved in the collection and management of data. DRL and JJS were responsible for drafting the manuscript. All authors provided critical review and endorsed the final version of the manuscript.

Funding This work was supported by the Australian Research Council (Grant number: FT140100399) and the NSW Department of Education and Communities School Sport Unit.

Competing interests None declared.

Ethics approval University of Newcastle and NSW Department of Education and Communities human research ethics committees.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. Kohl HW, Craig CL, Lambert EV, *et al*. The pandemic of physical inactivity: global action for public health. *Lancet* 2012;380:294–305.
2. Morrow JR Jr, Tucker JS, Jackson AW, *et al*. Meeting physical activity guidelines and health-related fitness in youth. *Am J Prev Med* 2013;44:439–44.
3. Jago R, Froberg K, Cooper AR, *et al*. Three-year changes in fitness and adiposity are independently associated with cardiovascular risk factors among young Danish children. *J Phys Act Health* 2010;7:37.
4. Jago R, Drews KL, McMurray RG, *et al*. BMI change, fitness change and cardiometabolic risk factors among 8th grade youth. *Pediatr Exerc Sci* 2013;25:52.
5. Hallal PC, Andersen LB, Bull FC, *et al*. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet* 2012;380:247–57.
6. Tomkinson GR, Olds T. *Secular changes in pediatric aerobic fitness test performance: the global picture*. Karger Publishers, 2007.
7. Runhaar J, Collard DC, Singh AS, *et al*. Motor fitness in Dutch youth: differences over a 26-year period (1980–2006). *J Sci Med Sport* 2010;13:323–8.
8. Tremblay MS, Shields M, Laviolette M, *et al*. *Fitness of Canadian children and youth: results from the 2007–2009 Canadian Health Measures Survey*. Statistics Canada, 2010.
9. Nishijima T, Kokudo S, Ohsawa S. Changes over the years in physical and motor ability in Japanese youth in 1964–97. *Int J Sport Health Sci* 2003;1:164–70.
10. Swinburn BA, Sacks G, Hall KD, *et al*. The global obesity pandemic: shaped by global drivers and local environments. *Lancet* 2011;378:804–14.
11. Blair SN, Kohl HW, Paffenbarger RS, *et al*. Physical fitness and all-cause mortality: a prospective study of healthy men and women. *J Am Med Assoc* 1989;262:2395–401.
12. Dietz WH. Health consequences of obesity in youth: childhood predictors of adult disease. *Pediatrics* 1998;101(Suppl 2):518–25.
13. Smith JJ, Eather N, Morgan PJ, *et al*. The health benefits of muscular fitness for children and adolescents: a systematic review and meta-analysis. *Sports Med* 2014;44:1209–23.

14. US Department of Health and Human Services. *Physical activity guidelines for Americans*. Washington DC: US Department of Health and Human Services, 2008.
15. Canadian Society for Exercise Physiology. *Canadian physical activity guidelines for youth (12–17 years)*. Canada: Public Health Agency of Canada, 2011.
16. Department of Health, Physical Activity, Health Improvement and Protection. *Stay active: a report on physical activity from the four home countries' chief medical officers*. London, 2011.
17. Department of Health. Start Active, Stay Active: A report on physical activity from the four home countries' Chief Medical Officers. Canberra: Department of Health, 2014.
18. Centers for Disease Control and Prevention. *Comprehensive school physical activity programs: a guide for schools*. Atlanta, GA: US Department of Health and Human Services, 2013.
19. Hills AP, Dengel DR, Lubans DR. Supporting public health priorities: recommendations for physical education and physical activity promotion in schools. *Prog Cardiovasc Dis* 2015;57:368–74.
20. Green K. Mission impossible? Reflecting upon the relationship between physical education, youth sport and lifelong participation. *Sport Educ Soc* 2014;19:357–75.
21. Hulteen RM, Lander NJ, Morgan PJ, *et al*. Validity and reliability of field-based measures for assessing movement skill competency in lifelong physical activities: a systematic review. *Sports Med* 2015;45:1443–54.
22. Vella SA, Cliff DP, Okely AD. Socio-ecological predictors of participation and dropout in organised sports during childhood. *Int J Behav Nutr Phys Act* 2014;11:62.
23. Dumith SC, Gigante DP, Domingues MR, *et al*. Physical activity change during adolescence: a systematic review and a pooled analysis. *Int J Epidemiol* 2011;40:685–98.
24. Corder K, Atkin AJ, Ekelund U, *et al*. What do adolescents want in order to become more active? *BMC Public Health* 2013;13:718.
25. Jones H, Millwar P, Buraimo B. *Adult participation in sport: analysis of the taking part survey*. England: Department for Culture, Media and Sport, 2011.
26. Australian Bureau of Statistics. *Participation in sport and physical recreation, Australia, 2013–2014*. Canberra: Commonwealth of Australia, 2015.
27. US Census Bureau. *Statistical abstract of the United States: Arts, recreation and travel*. United States, 2012.
28. Babic MJ, Morgan PJ, Plotnikoff RC, *et al*. Physical activity and physical self-concept in youth: systematic review and meta-analysis. *Sports Med* 2014;44:1589–601.
29. Bauman AE, Reis RS, Sallis JF, *et al*. Correlates of physical activity: why are some people physically active and others not? *Lancet* 2012;380:258–71.
30. Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). *BMJ* 2012;345:e5888.
31. Dobbins M, Husson H, DeCorby K, *et al*. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. *Cochrane Database Syst Rev* 2013;(2):CD007651.
32. Yildirim M, van Stralen MM, Chinapaw MJ, *et al*. For whom and under what circumstances do school-based energy balance behavior interventions work? Systematic review on moderators. *Int J Pediatr Obes* 2011;6:e46–57.
33. Morgan PJ, Young MD, Smith JJ, *et al*. Targeted health behavior interventions promoting physical activity: a conceptual model. *Exerc Sport Sci Rev* 2016;44:71–80.
34. Naylor PJ, Nettlefold L, Race D, *et al*. Implementation of school based physical activity interventions: a systematic review. *Prev Med* 2015;72:95–115.
35. Sutherland R, Campbell E, Lubans DR, *et al*. 'Physical Activity 4 Everyone' school-based intervention to prevent decline in adolescent physical activity levels: 12 month (mid-intervention) report on a cluster randomised trial. *Br J Sports Med* 2016;50:488–95.
36. Lubans DR, Morgan PJ, Dewar D, *et al*. The Nutrition and Enjoyable Activity for Teen Girls (NEAT girls) randomized controlled trial for adolescent girls from disadvantaged secondary schools: rationale, study protocol, and baseline results. *BMC Public Health* 2010;10:652–65.
37. Lubans DR, Morgan PJ, Okely AD, *et al*. Preventing obesity among adolescent girls: one-year outcomes of the Nutrition and Enjoyable Activity for Teen Girls (NEAT Girls) cluster randomized controlled trial. *Arch Pediatr Adolesc Med* 2012;166:821–7.
38. Dewar DL, Morgan PJ, Plotnikoff RC, *et al*. The Nutrition and Enjoyable Activity for Teen Girls study: a cluster randomized controlled trial. *Am J Prev Med* 2013;45:313–17.
39. Smith JJ, Morgan PJ, Plotnikoff RC, *et al*. Rationale and study protocol for the 'Active Teen Leaders Avoiding Screen-time' (ATLAS) group randomized controlled trial: an obesity prevention intervention for adolescent boys from schools in low-income communities. *Contemp Clin Trials* 2014;37:106–19.
40. Smith JJ, Morgan PJ, Plotnikoff RC, *et al*. Smart-phone obesity prevention trial for adolescent boys in low-income communities: the ATLAS RCT. *Pediatrics* 2014;134:e723–e31.
41. Lubans DR, Smith JJ, Morgan PJ, *et al*. Mediators of psychological well-being in adolescent boys. *J Adolesc Health* 2016;58:230–6.
42. Damschroder LJ, Aron DC, Keith RE, *et al*. Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. *Implement Sci* 2009;4:50.
43. Lubans DR, Smith JJ, Skinner G, *et al*. Development and implementation of a smartphone application to promote physical activity and reduce screen-time in adolescent boys. *Front Public Health* 2014;2:42.
44. Chan AW, Tetzlaff JM, Altman DG, *et al*. SPIRIT 2013 statement: defining standard protocol items for clinical trials. *Ann Intern Med* 2013;158:200–7.
45. Moher D, Hopewell S, Schulz KF, *et al*. CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. *BMJ* 2010;340:c869.
46. Glasgow RE, Vogt TM, Boles SM. Evaluating the public health impact of health promotion interventions: the RE-AIM framework. *Am J Public Health* 1999;89:1322–7.
47. Dzewaltowski DA, Estabrooks PA, Glasgow RE. The future of physical activity behavior change research: what is needed to improve translation of research into health promotion practice? *Exerc Sport Sci Rev* 2004;32:57–63.
48. Institute of Medicine. *Fitness measures and health outcomes in youth*. Washington DC: National Academies Press, 2012.
49. Ortega FB, Ruiz JR, Castillo MJ, *et al*. Physical fitness in childhood and adolescence: a powerful marker of health. *Int J Obes (Lond)* 2008;32:1–11.
50. Lubans DR, Morgan PJ, Aguiar EJ, *et al*. Randomized controlled trial of the Physical Activity Leaders (PALs) program for adolescent boys from disadvantaged secondary schools. *Prev Med* 2011;52:239–46.
51. Moulding NT, Silagy CA, Weller DP. A framework for effective management of change in clinical practice: dissemination and implementation of clinical practice guidelines. *Qual Health Care* 1999;8:177–83.
52. Bandura A. *Social foundations of thought and action: a social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall, 1986.
53. Deci E, Ryan R. *Instrinsic motivation and self-determination in human behaviour*. New York, NY: Plenum, 1985.
54. Hagger MS, Chatzisarantis NL, Culverhouse T, *et al*. The processes by which perceived autonomy support in physical education promotes leisure-time physical activity intentions and behavior: a trans-contextual model. *J Educ Psychol* 2003;95:784.
55. B Owen K, Smith J, Lubans DR, *et al*. Self-determined motivation and physical activity in children and adolescents: a systematic review and meta-analysis. *Prev Med* 2014;67:270–9.
56. Chatzisarantis NL, Hagger MS. Effects of an intervention based on self-determination theory on self-reported leisure-time physical activity participation. *Psychol Health* 2009;24:29–48.
57. Beauchamp MR, Barling J, Morton KL. Transformational teaching and adolescent self-determined motivation, self-efficacy, and intentions to engage in leisure time physical activity: a randomised controlled pilot trial. *Appl Psychol Health Well Being* 2011;3:127–50.
58. Cheon SH, Reeve J, Moon IS. Experimentally based, longitudinally designed, teacher-focused intervention to help physical education teachers be more autonomy supportive toward their students. *J Sport Exerc Psychol* 2012;34:365–96.
59. Lonsdale C, Rosenkranz RR, Sanders T, *et al*. A cluster randomized controlled trial of strategies to increase adolescents' physical activity and motivation in physical education: results of the Motivating Active Learning in Physical Education (MALP) trial. *Prev Med* 2013;57:696–702.
60. Lubans DR, Morgan PJ, Weaver K, *et al*. Rationale and study protocol for the Supporting Children's Outcomes using Rewards, Exercise and Skills (SCORES) group randomized controlled trial: a physical activity and fundamental movement skills intervention for primary schools in low-income communities. *BMC Public Health* 2012;12:427.
61. Lubans DR, Smith JJ, Harries SK, *et al*. Development, test-retest reliability and construct validity of the resistance training skills battery. *J Strength Cond Res* 2014;28:1373–80.

62. Resnicow K, Baranowski T, Ahluwalia J, *et al*. Cultural sensitivity in public health: defined and demystified. *Ethn Dis* 1998;9:10–21.
63. Lenhart A. *Teens, social media and technology overview 2015*. Pew Research Center, 2015.
64. Cooper Institute for Aerobics Research. *Fitnessgram: test administration manual*. Champaign, IL: Human Kinetics, 1999.
65. Lubans DR, Morgan P, Callister R, *et al*. Test–retest reliability of a battery of field-based health-related fitness measures for adolescents. *J Sports Sci* 2011;29:685–93.
66. Castro-Piñero J, Ortega FB, Artero EG, *et al*. Assessing muscular strength in youth: usefulness of standing long jump as a general index of muscular fitness. *J Strength Cond Res* 2010;24:1810–17.
67. Ruiz JR, Castro-Piñero J, España-Romero V, *et al*. Field-based fitness assessment in young people: the ALPHA health-related fitness test battery for children and adolescents. *Br J Sports Med* 2011;45:518–24.
68. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatr Obes* 2012;7:284–94.
69. Francis K, Feinstein R. A simple height-specific and rate-specific step test for children. *South Med J* 1991;84:169–74.
70. Barnett L, Reynolds J, Faigenbaum AD, *et al*. Rater agreement of a test battery designed to assess adolescents' resistance training skill competency. *J Sci Med Sport* 2015;18:72–6.
71. Phillips LR, Parfitt G, Rowlands AV. Calibration of the GENEA accelerometer for assessment of physical activity intensity in children. *J Sci Med Sport* 2013;16:124–8.
72. Scott JJ, Morgan PJ, Plotnikoff RC, *et al*. Reliability and validity of a single-item physical activity measure for adolescents. *J Paediatr Child Health* 2015;51:787–93.
73. Martínez-Gómez D, Welk GJ, Puertollano MA, *et al*. Associations of physical activity with muscular fitness in adolescents. *Scand J Med Sci Sports* 2011;21:310–17.
74. Hardy LL, Booth ML, Okely AD. The reliability of the adolescent sedentary activity questionnaire (ASAQ). *Prev Med* 2007;45:71–4.
75. Foehr UG. *Media multitasking among American youth: prevalence, predictors and pairings*. Menlo Park, CA: Henry J. Kaiser Family Foundation, 2006.
76. Wolfson AR, Carskadon MA. Sleep schedules and daytime functioning in adolescents. *Child Dev* 1998;69:875–87.
77. Wolfson AR, Carskadon MA, Acebo C, *et al*. Evidence for the validity of a sleep habits survey for adolescents. *Sleep* 2003;26:213–17.
78. Hardy LL, King L, Espinel P, *et al*. *NSW schools Physical Activity and Nutrition Survey (SPANS) 2010: Full Report*. Sydney: NSW Ministry of Health, 2010.
79. Watson JF, Collins CE, Sibbritt DW, *et al*. Reproducibility and comparative validity of a food frequency questionnaire for Australian children and adolescents. *Int J Behav Nutr Phys Act* 2009;6:62.
80. Marsh HW, Martin AJ, Jackson S. Introducing a short version of the physical self description questionnaire: new strategies, short-form evaluative criteria, and applications of factor analyses. *J Sport Exerc Psychol* 2010;32:438.
81. Diener E, Wirtz D, Tov W, *et al*. New well-being measures: short scales to assess flourishing and positive and negative feelings. *Soc Indic Res* 2010;97:143–56.
82. Markland D, Tobin V. A modification to the behavioural regulation in exercise questionnaire to include an assessment of amotivation. *J Sport Exerc Psychol* 2004;26:191–6.
83. Sánchez-López M, Martínez-Vizcaíno V, García-Hermoso A, *et al*. Construct validity and test–retest reliability of the International Fitness Scale (IFIS) in Spanish children aged 9–12 years. *Scand J Med Sci Sports* 2015;25:543–51.
84. Morgan P, Bourke S. Non-specialist teachers' confidence to teach PE: the nature and influence of personal school experiences in PE. *Phys Educ Sport Pedagog* 2008;13:1–29.
85. Morgan PJ, Hansen V. Classroom teachers' perceptions of the impact of barriers to teaching physical education on the quality of physical education programs. *Res Q Exerc Sport* 2008;79:506–16.
86. Hagger MS, Chatzisarantis N, Barkoukis V, *et al*. Perceived autonomy support in physical education and leisure-time physical activity: a cross-cultural evaluation of the trans-contextual model. *J Educ Psychol Rev* 2005;97:376–90.
87. Assmann SF, Pocock SJ, Enos LE, *et al*. Subgroup analysis and other (mis)uses of baseline data in clinical trials. *Lancet* 2000;355:1064–9.

A school-based intervention incorporating smartphone technology to improve health-related fitness among adolescents: rationale and study protocol for the NEAT and ATLAS 2.0 cluster randomised controlled trial and dissemination study

David R Lubans, Jordan J Smith, Louisa R Peralta, Ronald C Plotnikoff, Anthony D Okely, Jo Salmon, Narelle Eather, Deborah L Dewar, Sarah Kennedy, Chris Lonsdale, Toni A Hilland, Paul Estabrooks, Tara L Finn, Emma Pollock and Philip J Morgan

BMJ Open 2016 6:
doi: 10.1136/bmjopen-2015-010448