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Camden Active Spaces: Does the Construction of Active School Playgrounds Influence Children's Physical Activity Levels? A Longitudinal Quasi-Experiment Protocol

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Complete List of Authors:	Smith, Lee; University College London, Epidemiology and Public Health Kipps, Courtney; University College London Hospital, Institute of Sport, Exercise and Health Aggio, Daniel; University College London, Epidemiology and Public Health Fox, Paul; Camden Borough Council, Robinson, Nigel; Camden Borough Council, Trend, Verena; Camden Borough Council, Munnery, Suzie; Camden Borough Council, Kelly, Barry; Camden and Islington Public Health, Hamer, Mark; University College London, Epidemiology and Public Health
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3 1 **Camden Active Spaces: Does the Construction of Active School Playgrounds Influence**
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5 2 **Children's Physical Activity Levels? A Longitudinal Quasi-Experiment Protocol**
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11 4 Lee Smith*, Health Behaviour Research Centre, Department of Epidemiology and Public

12 Health, University College London, London, UK, WC1E 6BT; lee.smith@ucl.ac.uk; 020 7679

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15 6 1812

16
17
18 7 Courtney Kipps, Institute Sport Exercise and Health, University College London Hospital,

19
20
21 8 London, UK

22
23
24 9 Daniel Aggio, Physical Activity Research Group, Department of Epidemiology and Public

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26
27 10 Health, London, UK

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29
30 11 Paul Fox, Camden Borough Council, London, UK

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33 12 Nigel Robinson, Camden Borough Council, London, UK

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36 13 Verena Trend, Camden Borough Council, London, UK

37
38
39 14 Suzie Munnery, Camden Borough Council, London, Uk

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41
42 15 Barry Kelly, Camden and Islington Public Health, London, Uk

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45 16 Mark Hamer, Physical Activity Research Group, Department of Epidemiology and Public

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48 17 Health, London, UK

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51 18 *Corresponding author

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54 19 **Key words: physical activity/ active play/ children/ school/ environment**
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3 38 **INTRODUCTION**
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6 39 Physical activity is essential for every facet of children's health. However, physical activity
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8 40 levels in British children are low. The school environment is a promising setting to increase
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10 41 children's physical activity but limited empirical evidence exists on how a change in the
11
12 42 outdoor physical school environment influences physical activity behaviour. London
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14 43 Borough of Camden is re-designing seven existing school playgrounds to engage children to
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16 44 become more physically active. The primary aim of this project is to evaluate how the use of
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18 45 bespoke and innovative design of 'space' can influence physical activity levels in young
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20 46 people.
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29 48 **METHOD AND ANALYSIS**
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32 49 This project will use a longitudinal quasi-experimental design with one baseline data
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34 50 collection session and two follow-ups. Between baseline and follow-up the school
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36 51 playgrounds will be re-designed. At baseline, a series of fitness tests, anthropometric and
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38 52 questionnaire measurements, and 7 day objective physical activity monitoring will be
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40 53 carried out on children. This will be repeated at follow-up. Multilevel regression modelling
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42 54 will be used to analyse the data.
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3 59 **ETHICS AND DISSEMINATION**
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6 60 The results of this study will be disseminated through peer-review publications and scientific
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8 61 presentations. Ethical approval was obtained through the University College London
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10 62 Research Ethics Committee (Reference number: 4400/002).
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3 77 **Strengths and Limitations of this Study**
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6 78 • Camden Active Spaces presents a unique opportunity to evaluate the impact of the
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8 79 construction of school “active playgrounds” on children’s physical activity, health,
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10 80 and wellbeing.

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13 81 • The use of objective measures of physical activity over seven consecutive days is
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15 82 strength of the present study.

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18 83 • The present study uses a longitudinal quasi-experimental design without control
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20 84 groups.
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3 96 **INTRODUCTION**
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6 97 Physical activity is essential for every facet of children's (aged 5 to 16 years) health. For
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8 98 example, higher levels of physical activity in children are associated with more favourable
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10 99 cardiovascular disease risk factors whereas excessive levels of sedentary behaviour have the
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12 100 reverse effect.[1,2] Physical activity can also benefit psychological health by aiding in the
13
14 101 prevention of anxiety and depressive symptoms and contributing to the improvement of
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16 102 self-esteem.[3] Importantly, rather than detracting from learning, more physical activity and
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18 103 breaks from sitting in school are thought to enhance cognitive function and academic
19
20 104 performance.[4] It is also more likely that active children will become active adults, since
21
22 105 some tracking of physical activity behaviour has been observed from childhood to
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24 106 adulthood.[5] However, in westernised countries current levels of physical activity in
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26 107 children are low as there are increasing opportunities to participate in sedentary
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28 108 activities.[6,7] For example, it is recommended that children engage in physical activity of
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30 109 moderate intensity for at least one hour a day, to maintain good health.[8] However, just
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32 110 24% of British girls and 32% of boys achieve this recommendation.[7] Physical inactivity is
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34 111 estimated to cost the NHS approximately £8 billion per year in health care costs alone.[8]
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36 112 Encouraging physically active lifestyles in children is therefore crucial in nurturing a healthy
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38 113 future generation of adults.
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47 114 A recent meta-analysis found that the effects of interventions to increase physical activity in
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49 115 children have been, at best, modest, and concluded that alternative approaches are
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51 116 required.[9] Children spend approximately 60% of their weekday in school where physical
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53 117 activity levels are at their lowest.[10,11] Therefore, the school environment is a promising
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55 118 setting for intervention. The majority of school-based interventions have focused on
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3 119 physical education (delivered once or twice a week) and have found only small effects.[12]
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5 120 Environments both facilitate and provide the arena for physical activity [13] although there
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7 121 is little robust empirical evidence concerning the effect of changing the physical
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9 122 environment on activity levels in children. Emerging data has suggested that a positive
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11 123 perception of the school play environment was associated with higher levels of moderate-
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13 124 vigorous physical activity (MVPA) during playtime.[14] In a 12 month intervention where the
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15 125 playground environment was redesigned with markings and physical structures, children's
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17 126 morning and lunchtime activity levels were increased 6 months post-intervention, although
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19 127 effects were not sustained at 12 months.[15] Previous studies have collected physical
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21 128 activity data during one school day only therefore it is questionable whether this data is
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23 129 reflective of habitual behaviour and so limits the ability to examine carry over effects
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25 130 outside the school environment (ie, at weekends and during evenings). Taken together, the
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27 131 emerging evidence suggests that the physical environment could play an important role in
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29 132 children's physical activity behaviour, but more robust evidence is required.
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40 **SETTING**

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43 135 Camden Borough Council is re-designing seven existing school playgrounds (five primary
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45 136 schools and two secondary schools), that are thought *not* to be conducive to physical
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47 137 activity/ active play, with exciting bespoke features to engage children to become more
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49 138 active. Example features include climbing frames, trampolines, monkey bars, and outdoor
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51 139 gyms, which have been designed based on themes emerging from qualitative work in each
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53 140 school. Camden Council's underlying goal is to encourage participation by creating
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55 141 opportunities for physical activity outside of traditional sports or team competition. This
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3 142 presents a unique opportunity to evaluate the impact of these structures on children's
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5 143 physical activity, health and wellbeing outcomes while addressing previous limitations in the
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7 144 literature (ie collecting activity data for a period >1day).
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14 146 **AIMS**

17 147 The *Camden Active Spaces* project encompasses two key elements; 1) redesign of the school
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19 148 playgrounds; 2) evaluation of the hypothesised benefits. In the present paper we focus on
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21 149 the evaluation only. Thus, the primary aim of this project is to evaluate the impact of the re-
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23 150 designed playgrounds on children's physical activity, wellbeing, engagement, and physical
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25 151 function/fitness.
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33 153 **METHOD AND ANALYSES**

36 154 The evaluation of *Camden Active Spaces* will use a longitudinal quasi-experimental design.
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38 155 Baseline data collection will take place in the Spring/Summer term 2014, follow-up I data
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40 156 collection will take place during the Autumn term 2014, and follow-up II during the Summer
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42 157 term of 2015 (see Figure 1). Between baseline and follow-up I (school summer holidays) the
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44 158 school playgrounds will be re-designed. A second follow-up will allow us to investigate if
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46 159 short-term effects of the intervention (if they exist) are sustained over a longer period. This
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48 160 evaluation has been funded by the Economic and Social Research Council, UK
49
50 161 (ES/M003795/1), whilst the core project (playground redesign) has been funded by Camden
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52 162 Clinical Commissioning Group and London Borough of Camden. Ethical approval was
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54 163 granted by the University College London Research Ethics Committee (4400/002).
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6 165 **Inclusion criteria**
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9 166 *School inclusion criteria*
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12 167 Seven schools located in the London Borough of Camden have been selected to receive the
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14 168 re-designed playgrounds and all seven schools have agreed to take part in the study.
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21 170 *Participant Inclusion criteria*
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24 171 We aim to randomly select approximately 100 children (see below power calculation) evenly
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26 172 distributed across school year groups (aged 5 to 11 years in primary school and aged 11 to
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28 173 16 years in secondary school) from each of the seven schools (total sample size 700).
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31 174 Children aged 17 to 18 years or any school leavers in 2014 will not be asked to participate in
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33 175 the current project, owing to time table restrictions due to final exams and potential loss to
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35 176 follow up. Students whose parents have not opted them out of the study will be eligible to
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37 177 participate (see section Ethics and Dissemination for details on obtaining consent).
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45 179 **Recruitment**
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48 180 The seven schools who will be receiving the redesigned playgrounds have previously been
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50 181 recruited into the study. To recruit children into the study presentations will be given to
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52 182 each year group within each school, during assemblies. The presentations will disseminate
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54 183 information on *Camden Active Spaces*, what would be involved if children were to take part
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56 184 in the study and benefits of the study to children and the school. At the end of the
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3 185 presentations children will be given participant study information sheets. In order to make
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5 186 parents aware of the study a parent information sheet will be emailed to all parents
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7 187 (translated into different languages where required), posted on the school webpage, in
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10 188 addition to hard copies being made available at the school. In an attempt to maximise
11
12 189 response rates and adherence to protocol, each child who completes the wear protocol will
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14 190 be awarded a one-month free swimming voucher and entered into a prize draw to win an
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16 191 iPod Touch (one iPod Touch will be awarded per school). All schools taking part in the study
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18 192 will be entered into a separate prize draw to win one of two Nintendo Wiis.
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26 194 **Procedures**

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29 195 Data collection procedures will take place over a period of 18 months. A team of trained
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31 196 researchers will collect data from each school on a date and time that is convenient for the
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33 197 school. Children will be invited to take part in data collection. Data collection sessions will
34
35 198 last approximately 30 minutes. A series of fitness tests and anthropometric measurements
36
37 199 will be carried out on children, in an appropriate room in the school (e.g. sports or assembly
38
39 200 hall). Once fitness tests and anthropometric measurements have been completed objective
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41 201 devices (accelerometers) will be given to children to monitor their physical activity
42
43 202 behaviour. Between four and seven days of accelerometer data are needed to provide a
44
45 203 reliable estimate of habitual physical activity.[16] Thus participants will be asked to wear
46
47 204 accelerometers for 7 consecutive days. On day seven participants will return the device to
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49 205 research staff at the school where they will then complete a questionnaire on their physical
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51 206 activity behaviour. This exact process will be repeated at follow-up I and follow-up II.
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208 **Measurement and instruments**209 *Accelerometer*

210 It is now recognised that accelerometers provide the most reliable and valid measurement
211 of activity in children [17] and are considered the gold standard approach. These wearable
212 motion sensors measure movement across three dimensions, thus providing minute-by-
213 minute time-stamped data on activity intensity, duration, and patterns across the day.

214 Objective physical activity monitoring has been successfully used in similar study settings to
215 the present project.[14,15,17,18]

216 The present evaluation will use the Actigraph GT3X accelerometer. This device is validated
217 and has been used in other studies with primary and high school children (see for example:
218 www.iconnect.co.uk and <http://www.cedar.iph.cam.ac.uk/research/directory/speedy/>). The

219 Actigraph GT3X is worn on a belt around the waist with the device itself positioned above
220 the right hip either over or under clothing. Children will be asked to wear the device during
221 waking hours every day for seven consecutive days, but not during water-based activities or
222 sleep.

223

224 *Fitness Tests*

225 A series of fitness tests will be carried out, following Standard Operating Procedure Forms,
226 on all children taking part in the study. Four fitness tests will be carried out to measure
227 aspects of general fitness: participants will be asked to perform the hand held

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3 228 Dynamometer test to assess grip strength, the standing horizontal jump test to assess leg
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5 229 power, the peak flow test to assess lung function, and the sit-and-reach test to assess
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7 230 flexibility. Participants' weight and body composition will be measured using the Tanita SC-
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9 231 330 Body Composition Analyser (Tanita Inc, IL, USA) and height will be measured using the
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11 232 Leicester Height Measure, from which BMI will be calculated kg/m^2 .
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234 *Questionnaires*

235 All children taking part in the study will be asked to complete a questionnaire. The
236 questionnaire will take approximately ten minutes to complete and includes questions on
237 standard demographics and physical activity, as well as potentially important correlates of
238 physical activity.

239 The Girls Health Enrichment Multi-Studies (GEMS) physical activity survey has been
240 embedded within the questionnaire to give a subjective measure of physical activity. GEMS
241 has validity and reliability equivalent to other self-report measures of physical activity [19]
242 and was deemed suitable for both primary and high school boys and girls by those who
243 designed the present study, owing to its simplicity.

244 The questionnaire also includes items on travel mode (as used in the iConnect Study;
245 www.iconnect.co.uk), diet, parents health (as used in the DASH study;
246 <http://dash.sphsu.mrc.ac.uk/>), and health related quality of life (Child Health Utility 9D;[20]
247 to allow for a cost evaluation of the project).

248 Teachers will be asked to complete the validated Strengths and Difficulties
249 questionnaire;[21] this questionnaire provides a measure of children's behaviour and

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3 250 mental health and takes approximately five minutes to complete per child. Head Teachers
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5 251 will also be asked to complete a questionnaire to allow for an understanding of differences
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7 252 between schools on “playground policy.” Example questions include, “If it is raining are
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10 253 children allowed to go outside and play?” And “How long do schools provide for recess?”
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16 255 **ANALYSIS**

19 256 *Outcome*

22 257 The primary outcome for this study will be change in average daily time spent in MVPA as
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24 258 recorded by the Actigraph accelerometer. In addition the study has been designed to collect
25
26 259 the following secondary outcomes using participant questionnaires and objective measures
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28 260 (1) change in average daily time spent sedentary, (2) change in average daily time spent in
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30 261 light and vigorous activity at different times of the day (playtimes at school, leisure time at
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32 262 home), (3) change in peak flow, sit-and-reach, grip strength, standing horizontal jump, and
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34 263 body mass index (BMI)/body composition, (4) change in other intra-personal variables
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36 264 recorded by questionnaires (e.g. Strength and Difficulties scores).
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266 266 *Quantitative analysis*

267 267 Raw data files will be extracted from each Actigraph device and processed using bespoke
268 268 software (Actilife) to quantify a range of features that will directly contribute to the
269 269 determination of active and sedentary time. Standard criteria will be employed in the
270 270 analysis and cleaning of accelerometry data, including the use of conventional guidelines to

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3 271 identify minimum wear time, differentiate non-wear time from prolonged periods of
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5 272 inactivity, and selecting valid cut-points for the identification of different activity intensity
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8 273 bands. Multilevel modelling will be used to analyse the data. This approach offers several
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10 274 advantages over simple regression models. We will be able to model changes in activity over
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12 275 the three assessment periods accounting for the inter-individual as well as intra-individual
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14 276 differences.
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21 278 *Sample size*
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24 279 A previous school based intervention to examine the effects of changes in playground
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26 280 structure on physical activity [17] demonstrated a small effect size ($d = 0.10$). Thus, based on
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28 281 these data, a sample size of $N=458$ would provide us with 80% power at 5% significance
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30 282 level to detect small differences in moderate intensity physical activity using a repeated
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32 283 measures design (calculated using G-Power). We will aim to recruit 100 children from each
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34 284 school to allow for dropout and incomplete Actigraph data.
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43 286 **ETHICAL CONSIDERATION AND DISSEMINATION**

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46 287 Firstly, head teachers from each school will be asked to provide explicit written consent for
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48 288 their schools and school children to take part in the study. Next, if parents do not want their
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50 289 child(ren) to take part in the study they will be given the option to “opt-out” their child(ren),
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52 290 instructions to parents on how to opt-out their child(ren) are provided in the parent study
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54 291 information sheet. Prior to data collection all high school (not primary school) children will
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56 292 be asked to provide explicit written assent.
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3 293 The findings from this study will be disseminated to academic researchers and to
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5 294 policymakers through several mechanisms. First, we will employ the usual avenues for
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7 295 dissemination of academic research, including conference presentations and journal
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9 296 articles. Second, we will disseminate this research via social media outlets such as the
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11 297 University College London – Physical Activity Research Group Twitter account. Third, with
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13 298 Camden Council, we will include this physical activity study within the regular programme of
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15 299 briefings that are presented to government departments interested in physical activity,
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17 300 including the Department of Health, the Department for Communities and Local
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19 301 Government, etc.
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28 303 **Competing interests**

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31 304 The authors declare that they have no competing interests.
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33

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35
36
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40 307 **Authors' contributions**

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44 308 LS, CK, and MH designed the study. All authors contributed to the development of the study
45
46 309 protocol. LS and MH drafted the manuscript. All authors assisted in drafting the manuscript.
47
48 310 All authors read and approved the final manuscript.
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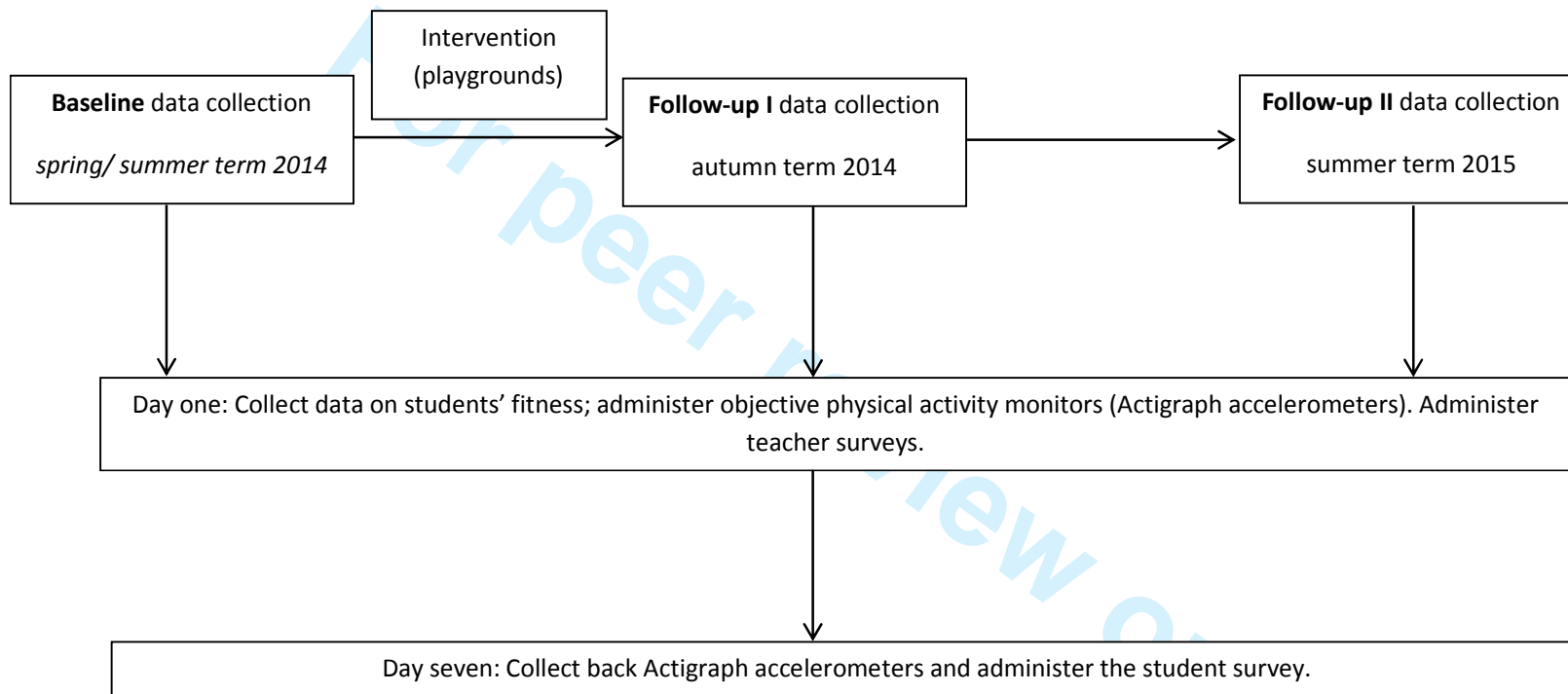
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Figure one: Overview of Study Design



STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract YES
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found YES
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported YES
Objectives	3	State specific objectives, including any prespecified hypotheses YES
Methods		
Study design	4	Present key elements of study design early in the paper YES
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection YES
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up YES
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants YES
Variables	7	(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case NA
		Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable YES
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group YES
Bias	9	Describe any efforts to address potential sources of bias YES
Study size	10	Explain how the study size was arrived at YES
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why YES

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3	Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding
4			YES
5			_____
6			(b) Describe any methods used to examine subgroups and interactions
7			NA
8			_____
9			(c) Explain how missing data were addressed
10			NA
11			_____
12			(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed
13			<i>Case-control study</i> —If applicable, explain how matching of cases and controls was
14			addressed
15			<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of
16			sampling strategy
17			NA
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19			(e) Describe any sensitivity analyses

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Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		NA
		(b) Give reasons for non-participation at each stage
		NA
		(c) Consider use of a flow diagram
		NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		NA
		(b) Indicate number of participants with missing data for each variable of interest
		NA
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)
		YES
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time
		NA
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure
		NA
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures
		NA
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		NA
		(b) Report category boundaries when continuous variables were categorized
		NA
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
		NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
		NA
Discussion		
Key results	18	Summarise key results with reference to study objectives
		NA
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
		YES
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
		NA
Generalisability	21	Discuss the generalisability (external validity) of the study results
		NA

Other information

Funding 22 Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

YES

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Camden Active Spaces: Does the Construction of Active School Playgrounds Influence Children's Physical Activity Levels? A Longitudinal Quasi-Experiment Protocol

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Primary Subject Heading:	Public health
Secondary Subject Heading:	Paediatrics
Keywords:	PREVENTIVE MEDICINE, PUBLIC HEALTH, SPORTS MEDICINE

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3 1 **Camden Active Spaces: Does the Construction of Active School Playgrounds Influence**
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5 2 **Children's Physical Activity Levels? A Longitudinal Quasi-Experiment Protocol**
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11 4 Lee Smith*, Health Behaviour Research Centre, Department of Epidemiology and Public

12 Health, University College London, London, UK, WC1E 6BT; lee.smith@ucl.ac.uk; 020 7679

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14
15 6 1812

16
17
18 7 Courtney Kipps, Institute Sport Exercise and Health, University College London Hospital,

19
20
21 8 London, UK

22
23
24 9 Daniel Aggio, Physical Activity Research Group, Department of Epidemiology and Public

25
26
27 10 Health, London, UK

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30 11 Paul Fox, Camden Borough Council, London, UK

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33 12 Nigel Robinson, Camden Borough Council, London, UK

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36 13 Verena Trend, Camden Borough Council, London, UK

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39 14 Suzie Munnery, Camden Borough Council, London, Uk

40
41
42 15 Barry Kelly, Camden and Islington Public Health, London, Uk

43
44
45 16 Mark Hamer, Physical Activity Research Group, Department of Epidemiology and Public

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48 17 Health, London, UK

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51 18 *Corresponding author

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54 19 **Key words: physical activity/ active play/ children/ school/ environment**
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20 **Word count: 2317**

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3 38 **INTRODUCTION**
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6 39 Physical activity is essential for every facet of children's health. However, physical activity
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8 40 levels in British children are low. The school environment is a promising setting to increase
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10 41 children's physical activity but limited empirical evidence exists on how a change in the
11
12 42 outdoor physical school environment influences physical activity behaviour. London
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14 43 Borough of Camden is re-designing seven existing school playgrounds to engage children to
15
16 44 become more physically active.
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21 45 The primary aim of this project is to evaluate the impact of the re-designed playgrounds on
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23 46 children's physical activity, wellbeing, engagement, and physical function/fitness.
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29 48 **METHOD AND ANALYSIS**
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32 49 This project will use a longitudinal quasi-experimental design. Seven experimental schools
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34 50 and one control school will take part. One baseline data collection session and two follow-
35
36 51 ups will be carried out. Between baseline and follow-up the experimental school
37
38 52 playgrounds will be re-designed. At baseline, a series of fitness tests, anthropometric and
39
40 53 questionnaire measurements, and 7 day objective physical activity monitoring (Actigraph
41
42 54 accelerometer) will be carried out on children (aged 5 to 16 years). This will be repeated at
43
44 55 follow-up. Changes in overall physical activity levels and levels during different times of the
45
46 56 day (eg, school breaks) will be examined. Multilevel regression modelling will be used to
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48 57 analyse the data.
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61 **ETHICS AND DISSEMINATION**

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9 62 The results of this study will be disseminated through peer-review publications and scientific
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11 63 presentations. Ethical approval was obtained through the University College London
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14 64 Research Ethics Committee (Reference number: 4400/002).
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3 78 **INTRODUCTION**
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6 79 Physical activity is essential for every facet of children's (aged 5 to 16 years) health. For
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8 80 example, higher levels of physical activity in children are associated with more favourable
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10 81 cardiovascular disease risk factors whereas excessive levels of sedentary behaviour have the
11
12 82 reverse effect.[1,2] Physical activity can also benefit psychological health by aiding in the
13
14 83 prevention of anxiety and depressive symptoms and contributing to the improvement of
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16 84 self-esteem.[3] Importantly, rather than detracting from learning, more physical activity and
17
18 85 breaks from sitting in school are thought to enhance cognitive function and academic
19
20 86 performance.[4] It is also more likely that active children will become active adults, since
21
22 87 some tracking of physical activity behaviour has been observed from childhood to
23
24 88 adulthood.[5] However, in westernised countries current levels of physical activity in
25
26 89 children are low as there are increasing opportunities to participate in sedentary
27
28 90 activities.[6,7] For example, it is recommended that children engage in physical activity of
29
30 91 moderate intensity for at least one hour a day, to maintain good health.[8] However, just
31
32 92 24% of British girls and 32% of boys achieve this recommendation.[7] Physical inactivity is
33
34 93 estimated to cost the NHS approximately £8 billion per year in health care costs alone.[8]
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36 94 Encouraging physically active lifestyles in children is therefore crucial in nurturing a healthy
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38 95 future generation of adults.
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47 96 A recent meta-analysis found that the effects of interventions to increase physical activity in
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49 97 children have been, at best, modest, and concluded that alternative approaches are
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51 98 required.[9] In the UK, children spend approximately 60% of their weekday in school where
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53 99 physical activity levels, particularly in girls, are low.[10,11] Environments both facilitate and
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55 100 provide the arena for physical activity [12]. Interventions that target the school environment
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3 101 may offer great opportunity to increase physical activity levels. However, there is little
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5 102 robust empirical evidence concerning the effect of changing the physical environment on
6
7 103 activity levels in children. Emerging data has suggested that a positive perception of the
8
9 104 school play environment was associated with higher levels of moderate-vigorous physical
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11 105 activity (MVPA) during playtime.[13] Moreover, the number of permanent play facilities in
12
13 106 school playgrounds has been found to be associated with higher physical activity levels.[14]
14
15 107 A recent review [15] on the value of playgrounds for children’s physical activity identified 13
16
17 108 experimental studies, which have produced mixed findings, likely owing to differences in
18
19 109 intervention design. For example, the review identified that reducing playground density
20
21 110 increased physical activity levels, but the provision of play equipment produced mixed
22
23 111 effects, whereas no effects were found on the provision of playground markings and
24
25 112 promotion of physical activity by teachers. Just one study investigated the impact of “major”
26
27 113 playground reconstruction on children’s physical activity behaviour [16] and concluded
28
29 114 renovated schoolyards to promote physical activity may increase the number of children
30
31 115 who are physically active and may reduce sedentary behaviours. However, physical activity
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33 116 data was collected using direct observation during the school day, only. This limits the ability
34
35 117 to examine carry over effects outside the school environment (ie, at weekends and during
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37 118 evenings). Taken together, the emerging evidence suggests that the physical environment
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39 119 could play an important role in children’s physical activity behaviour, but more robust
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41 120 evidence is required.
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3 124 **SETTING**
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6 125 Camden Borough Council is re-designing seven existing school playgrounds (five primary schools and
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8 126 two secondary schools), that are thought not to be conducive to physical activity/ active play, with
9
10 127 exciting bespoke features to engage children to become more active. Each school will receive a
11
12 128 unique playground design, for example displayed in Figure 1. Example features include new
13
14 129 Astroturf games pitches, climbing frames, trampolines, monkey bars, and outdoor gyms, which have
15
16 130 been designed based on themes (eg, ancient ruins, volcanoes, clouds etc.) emerging from qualitative
17
18 131 work with children and teachers in each school. The research team did not carry out the qualitative
19
20 132 work nor did they provide input into the design of the playgrounds. Camden Council's underlying
21
22 133 goal is to encourage participation by creating opportunities for physical activity outside of
23
24 134 traditional sports or team competition. This presents a unique opportunity to evaluate the
25
26 135 impact of these structures on children's physical activity, health and wellbeing outcomes
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28 136 while addressing previous limitations in the literature (ie, collecting activity only in school).
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37 138 We hypothesise that the new play grounds will increase young peoples' time spent in both light and
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39 139 moderate-to-vigorous physical activity and reduce sedentary behaviour during break time, and
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41 140 consequently improve levels of general fitness (eg, grip and leg strength, peak flow and adiposity).
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47 142 **AIMS**
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50 143 The *Camden Active Spaces* project consists of two key elements; 1) redesign of the school
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52 144 playgrounds; 2) evaluation of the hypothesised benefits. In the present paper we focus on
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54 145 the evaluation only. Thus, the primary aim of this project is to evaluate the impact of the re-
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3 146 designed playgrounds on children's physical activity, wellbeing, engagement, and physical
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5 147 function/fitness.
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10 11 149 **METHOD AND ANALYSES**

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15 150 The evaluation of *Camden Active Spaces* will use a longitudinal quasi-experimental design.
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17 151 Baseline data collection will take place in the Spring/Summer term 2014, follow-up I data
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19 152 collection will take place during the Autumn term 2014, and follow-up II during the Summer
20
21 153 term of 2015 (see Figure 2). Between baseline and follow-up I (school summer holidays) the
22
23 154 school playgrounds will be re-designed. A second follow-up will allow us to investigate if
24
25 155 short-term effects of the intervention (if they exist) are sustained over a longer period. This
26
27 156 evaluation has been funded by the Economic and Social Research Council, UK
28
29 157 (ES/M003795/1), whilst the core project (playground redesign) has been funded by Camden
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31 158 Clinical Commissioning Group and London Borough of Camden. Ethical approval was
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33 159 granted by the University College London Research Ethics Committee (4400/002).
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43 161 **Inclusion criteria**

44 45 162 *School inclusion criteria*

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49 163 Seven schools located in the London Borough of Camden have been selected to receive the
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51 164 re-designed playgrounds and all seven schools have agreed to take part in the study.
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3 166 In addition to the seven experimental schools one control school will be recruited into the study.
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5 167 This school will be located in the London Borough of Camden and it will not be receiving a new
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7 168 playground design, moreover, it will not differ from experimental schools based on student
8
9 169 demographics or school policy. Owing to resources it is only feasible to collect data from a single
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11 170 control school. The authors acknowledge that an equal number of controls to experimental schools
12
13 171 would allow for a more robust experimental design.
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16 17 172 *Participant Inclusion criteria*

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20 173 We aim to randomly select approximately 100 children (see below power calculation) evenly
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22 174 distributed across school year groups (aged 5 to 11 years in primary school and aged 11 to
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24 175 16 years in secondary school) from each of the eight schools (total sample size 800).
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27 176 Children aged 17 to 18 years or any school leavers in 2014 will not be asked to participate in
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29 177 the current project, owing to time table restrictions due to final exams and potential loss to
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31 178 follow up. Students whose parents have not opted them out of the study will be eligible to
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33 179 participate (see section Ethics and Dissemination for details on obtaining consent).
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40 181 **Recruitment**

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43 182 The seven schools who will be receiving the redesigned playgrounds have previously been
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45 183 recruited into the study by Camden Borough Council. To recruit children into the study
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47 184 presentations will be given to each year group within each school, during assemblies. The
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49 185 presentations will disseminate information on *Camden Active Spaces*, what would be
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51 186 involved if children were to take part in the study and benefits of the study to children and
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53 187 the school. At the end of the presentations children will be given participant study
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55 188 information sheets. In order to make parents aware of the study a parent information sheet
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3 189 will be emailed to all parents (translated into different languages where required), posted
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5 190 on the school webpage, in addition to hard copies being made available at the school. In an
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7 191 attempt to maximise response rates and adherence to protocol, each child who completes
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9 192 the wear protocol will be awarded a one-month free swimming voucher and entered into a
10
11 193 prize draw to win an iPod Touch (one iPod Touch will be awarded per school). All schools
12
13 194 taking part in the study will be entered into a separate prize draw to win one of two
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17 195 Nintendo Wiis.
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197 **Procedures**

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26 198 Data collection procedures will take place over a period of 12 months. A team of trained
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28 199 researchers will collect data from each school on a date and time that is convenient for the
29
30 200 school. Children will be invited to take part in data collection. Data collection sessions will
31
32 201 last approximately 30 minutes. A series of fitness tests and anthropometric measurements
33
34 202 will be carried out on children, in an appropriate room in the school (e.g. sports or assembly
35
36 203 hall). Once fitness tests and anthropometric measurements have been completed objective
37
38 204 devices (accelerometers) will be given to children to monitor their physical activity
39
40 205 behaviour. Between four and seven days of accelerometer data are needed to provide a
41
42 206 reliable estimate of habitual physical activity.[17] Thus participants will be asked to wear
43
44 207 objective devices for 7 consecutive days. On day seven participants will return the device to
45
46 208 research staff at the school where they will then complete a questionnaire on their physical
47
48 209 activity behaviour. This exact process will be repeated at follow-up I and follow-up II.
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3 211 **Measurement and instruments**
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6 212 *Accelerometer*
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9 213 It is now recognised that accelerometers provide the most reliable and valid measurement
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11 214 of activity in children [16] and are considered the gold standard approach. These wearable
12
13 215 motion sensors measure movement across three dimensions, thus providing minute-by-
14
15 216 minute time-stamped data on activity intensity, duration, and patterns across the day.
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19 217 Objective physical activity monitoring has been successfully used in similar study settings to
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21 218 the present project.[14,18, 19]
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24 219 The present evaluation will use the Actigraph GT3X accelerometer. This device is validated
25
26 220 and has been used in other studies with primary and high school children (see for example:
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28 221 www.iconnect.co.uk and <http://www.cedar.iph.cam.ac.uk/research/directory/speedy/>). The
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31 222 Actigraph GT3X is worn on a belt around the waist with the device itself positioned above
32
33 223 the right hip either over or under clothing. We will employ a sampling frequency of 30 hz.
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36 224 Children will be asked to wear the device during waking hours every day for seven
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38 225 consecutive days, but not during water-based activities or sleep.
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45 227 *Fitness Tests*
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48 228 A series of fitness tests will be carried out, following Standard Operating Procedure Forms,
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50 229 on all children taking part in the study. These tests have been extensively validated and used
51
52 230 in previous cohort studies of children (eg, <http://www.chasestudy.ac.uk/study->
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55 231 measurement) Four fitness tests will be carried out to measure aspects of general fitness:
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57 232 participants will be asked to perform the hand held Dynamometer test to assess grip
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3 233 strength, the standing horizontal jump test to assess leg power, the peak flow test to assess
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5 234 lung function, and the sit-and-reach test to assess flexibility. Participants' weight and body
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8 235 composition will be measured using the Tanita SC-330 Body Composition Analyser (Tanita
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10 236 Inc, IL, USA) and height will be measured using the Leicester Height Measure, from which
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12 237 BMI will be calculated kg/m^2 .
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19 239 *Questionnaires*

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22 240 All children taking part in the study will be asked to complete a questionnaire. The
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24 241 questionnaire will take approximately ten minutes to complete and includes questions on
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26 242 standard demographics and physical activity, as well as potentially important correlates of
27
28 243 physical activity. Teaching assistants and research staff will assist all children in completing
29
30 244 questionnaires.
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34 245 The Girls Health Enrichment Multi-Studies (GEMS) physical activity survey has been
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36 246 embedded within the questionnaire to give a subjective measure of physical activity and
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38 247 provide an understanding of which specific physical activity behaviours are influenced by
39
40 248 the playground redesign, if any. GEMS has validity and reliability equivalent to other self-
41
42 249 report measures of physical activity [20] and was deemed suitable for both primary and high
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44 250 school boys and girls by those who designed the present study, owing to its simplicity. The
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46 251 questionnaire also includes items on travel mode (as used in the iConnect Study;
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48 252 www.iconnect.co.uk).
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54 253 Teachers will be asked to complete the validated Strengths and Difficulties
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56 254 questionnaire;[21] this questionnaire provides a measure of children's behaviour, mental
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3 255 health, engagement and well-being and takes approximately five minutes to complete per
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5 256 child.
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9 257 Each school has one Head Teacher. Head Teachers (n=8) will be asked to complete a
10
11 258 questionnaire to allow for an understanding of differences between schools on “playground
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13 259 policy.” Questions include, “During what type of weather are children not allowed to go
14
15 260 outside during scheduled breaks (i.e. rain/ snow)?” “Are any sections of the current
16
17 261 playground out of use during bad weather (i.e. school field when raining), if yes please
18
19 262 specify?” “When children cannot go outside on scheduled breaks, owing to bad weather,
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21 263 where do they spend their break?” and “Are there any current initiatives/programs to
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23 264 promote physical activity and/or healthy lifestyles in your school, if yes please specify?”
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27 265 Head teachers will be asked to complete an identical survey at follow-up to allow for the
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29 266 assessment of changes in “playground policy” between each time point.
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36 268 **ANALYSIS**

39 269 *Outcome*

42 270 The primary outcome for this study will be change in average daily time spent in MVPA as
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44 271 recorded by the Actigraph accelerometer. In addition the study has been designed to collect
45
46 272 the following secondary outcomes using participant questionnaires and objective measures
47
48 273 (1) change in average daily time spent sedentary, (2) change in average daily time spent in
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50 274 light and vigorous activity at different times of the day (playtimes at school, leisure time at
51
52 275 home), (3) change in peak flow, sit-and-reach, grip strength, standing horizontal jump, and
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54 276 body mass index (BMI)/body composition, (4) change in Strength and Difficulties scores.
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7 278 *Quantitative analysis*

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9 279 Raw data files will be extracted from each Actigraph device and processed using bespoke
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11 280 software (Actilife) to quantify a range of features that will directly contribute to the
12
13 281 determination of active and sedentary time. We intend to follow methods used in the
14
15 282 International Children's Accelerometry Database study that incorporated children aged 4-18
16
17 283 yrs old [2]. Briefly, data files will be reintegrated to a 60-second epoch and non-wear time
18
19 284 defined as 60 minutes of consecutive zeros, allowing for 2 minutes of non-zero
20
21 285 interruptions. All children with at least 1 day with at least 500 minutes of measured monitor
22
23 286 wear time between 7 AM and midnight will be included. Total physical activity will be
24
25 287 expressed as total counts, including sedentary minutes, divided by measured time per day
26
27 288 (counts/min, cpm). Time spent sedentary will be defined as all minutes showing less than
28
29 289 100 cpm and MVPA time as minutes showing more than 3000 cpm. Multilevel modelling will
30
31 290 be used to analyse the data. This approach offers several advantages over simple regression
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33 291 models. We will be able to model changes in activity over the three assessment periods
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35 292 accounting for the inter-individual as well as intra-individual differences.
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47 294 *Sample size*

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49 295 A previous school based intervention to examine the effects of changes in playground
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51 296 structure on physical activity [18] demonstrated a small effect size ($d = 0.10$). Thus, based on
52
53 297 these data, a sample size of $N = 458$ would provide us with 80% power at 5% significance
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55 298 level to detect small differences in moderate intensity physical activity using a repeated
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3 299 measures design (calculated using G-Power). We will aim to recruit 100 children from each
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5 300 school to allow for dropout and incomplete Actigraph data.
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12 302 **ETHICAL CONSIDERATION AND DISSEMINATION**
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15 303 Firstly, head teachers from each school will be asked to provide explicit written consent for
16
17 304 their schools and school children to take part in the study. Next, if parents (of primary and
18
19 305 secondary school children) do not want their child(ren) to take part in the study they will be
20
21 306 given the option to “opt-out” their child(ren), instructions to parents on how to opt-out
22
23 307 their child(ren) are provided in the parent study information sheet. Prior to data collection
24
25 308 all high school (not primary school) children will be asked to provide explicit written assent.
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30 309 The findings from this study will be disseminated to academic researchers and to
31
32 310 policymakers through several mechanisms. First, we will employ the usual avenues for
33
34 311 dissemination of academic research, including conference presentations and journal
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36 312 articles. Second, we will disseminate this research via social media outlets such as the
37
38 313 University College London – Physical Activity Research Group Twitter account. Third, with
39
40 314 Camden Council, we will include this physical activity study within the regular programme of
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42 315 briefings that are presented to government departments interested in physical activity,
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44 316 including the Department of Health, the Department for Communities and Local
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46 317 Government, etc.
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3 320 **Competing interests**
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6 321 The authors declare that they have no competing interests.
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9 322 **Funding**
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11
12 323 This work was supported by The Economic and Social Research Council, UK (ES/M003795/1)
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15 324 **Authors' contributions**
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18 325 Lee Smith, Courtney Kipps, Daniel Aggio, Paul Fox, Nigel Robinson, Verena Trend, Suzie
19

20 326 Munnery, Barry Kelly, and Mark Hamer made substantial contribution to the concept and
21

22 327 design of the study. Lee Smith drafted the manuscript and Courtney Kipps, Daniel Aggio,
23

24 328 Paul Fox, Nigel Robinson, Verena Trend, Suzie Munnery, Barry Kelly, and Mark Hamer
25

26 329 revised it critically for important intellectual content. Lee Smith, Courtney Kipps, Daniel
27

28 330 Aggio, Paul Fox, Nigel Robinson, Verena Trend, Suzie Munnery, Barry Kelly, and Mark Hamer
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30 331 approved the final version of the manuscript to be published.
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6 389 **Figure Legends**
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9 390 **Figure 1: Example of new playground designs**
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12 391 **Figure 2: Overview of study design**
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For peer review only

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3 1 **Camden Active Spaces: Does the Construction of Active School Playgrounds Influence**
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5 2 **Children's Physical Activity Levels? A Longitudinal Quasi-Experiment Protocol**
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11 4 Lee Smith*, Health Behaviour Research Centre, Department of Epidemiology and Public

12 Health, University College London, London, UK, WC1E 6BT; lee.smith@ucl.ac.uk; 020 7679

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19 7 Courtney Kipps, Institute Sport Exercise and Health, University College London Hospital,

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22 8 London, UK

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25 9 Daniel Aggio, Physical Activity Research Group, Department of Epidemiology and Public

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28 10 Health, London, UK

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31 11 Paul Fox, Camden Borough Council, London, UK

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34 12 Nigel Robinson, Camden Borough Council, London, UK

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37 13 Verena Trend, Camden Borough Council, London, UK

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40 14 Suzie Munnery, Camden Borough Council, London, UK

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43 15 Barry Kelly, Camden and Islington Public Health, London, UK

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46 16 Mark Hamer, Physical Activity Research Group, Department of Epidemiology and Public

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49 17 Health, London, UK

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52 18 *Corresponding author

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55 19 **Key words: physical activity/ active play/ children/ school/ environment**
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For peer review only

38 INTRODUCTION

39 Physical activity is essential for every facet of children’s health. However, physical activity
40 levels in British children are low. The school environment is a promising setting to increase
41 children’s physical activity but limited empirical evidence exists on how a change in the
42 outdoor physical school environment influences physical activity behaviour. London
43 Borough of Camden is re-designing seven existing school playgrounds to engage children to
44 become more physically active.

45 **The primary aim of this project is to evaluate the impact of the re-designed playgrounds on**
46 **children’s physical activity, wellbeing, engagement, and physical function/fitness.**

48 METHOD AND ANALYSIS

49 **This project will use a longitudinal quasi-experimental design. Seven experimental schools**
50 **and one control school will take part. One baseline data collection session and two follow-**
51 **ups will be carried out. Between baseline and follow-up the experimental school**
52 **playgrounds will be re-designed. At baseline, a series of fitness tests, anthropometric and**
53 **questionnaire measurements, and 7 day objective physical activity monitoring (Actigraph**
54 **accelerometer) will be carried out on children (aged 5 to 16 years). This will be repeated at**
55 **follow-up. Changes in overall physical activity levels and levels during different times of**
56 **the day (eg, school breaks) will be examined. Multilevel regression modelling will be used**
57 **to analyse the data.**

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61 ETHICS AND DISSEMINATION

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9 62 The results of this study will be disseminated through peer-review publications and scientific
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11 63 presentations. Ethical approval was obtained through the University College London
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14 64 Research Ethics Committee (Reference number: 4400/002).
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3 78 **INTRODUCTION**
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6 79 Physical activity is essential for every facet of children's (aged 5 to 16 years) health. For
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8 80 example, higher levels of physical activity in children are associated with more favourable
9
10 81 cardiovascular disease risk factors whereas excessive levels of sedentary behaviour have the
11
12 82 reverse effect.[1,2] Physical activity can also benefit psychological health by aiding in the
13
14 83 prevention of anxiety and depressive symptoms and contributing to the improvement of
15
16 84 self-esteem.[3] Importantly, rather than detracting from learning, more physical activity and
17
18 85 breaks from sitting in school are thought to enhance cognitive function and academic
19
20 86 performance.[4] It is also more likely that active children will become active adults, since
21
22 87 some tracking of physical activity behaviour has been observed from childhood to
23
24 88 adulthood.[5] However, in westernised countries current levels of physical activity in
25
26 89 children are low as there are increasing opportunities to participate in sedentary
27
28 90 activities.[6,7] For example, it is recommended that children engage in physical activity of
29
30 91 moderate intensity for at least one hour a day, to maintain good health.[8] However, just
31
32 92 24% of British girls and 32% of boys achieve this recommendation.[7] Physical inactivity is
33
34 93 estimated to cost the NHS approximately £8 billion per year in health care costs alone.[8]
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36 94 Encouraging physically active lifestyles in children is therefore crucial in nurturing a healthy
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38 95 future generation of adults.
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47 **A recent meta-analysis found that the effects of interventions to increase physical activity**
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49 **in children have been, at best, modest, and concluded that alternative approaches are**
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51 **required.[9] In the UK, children spend approximately 60% of their weekday in school**
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53 **where physical activity levels, particularly in girls, are low.[10,11] Environments both**
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55 **facilitate and provide the arena for physical activity [12]. Interventions that target the**
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3 101 school environment may offer great opportunity to increase physical activity levels.
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5 102 However, there is little robust empirical evidence concerning the effect of changing the
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7 103 physical environment on activity levels in children. Emerging data has suggested that a
8
9 104 positive perception of the school play environment was associated with higher levels of
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11 105 moderate-vigorous physical activity (MVPA) during playtime.[13] Moreover, the number
12
13 106 of permanent play facilities in school playgrounds has been found to be associated with
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15 107 higher physical activity levels.[14] A recent review [15] on the value of playgrounds for
16
17 108 children's physical activity identified 13 experimental studies, which have produced mixed
18
19 109 findings, likely owing to differences in intervention design. For example, the review
20
21 110 identified that reducing playground density increased physical activity levels, but the
22
23 111 provision of play equipment produced mixed effects, whereas no effects were found on
24
25 112 the provision of playground markings and promotion of physical activity by teachers. Just
26
27 113 one study investigated the impact of "major" playground reconstruction on children's
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29 114 physical activity behaviour [16] and concluded renovated schoolyards to promote physical
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31 115 activity may increase the number of children who are physically active and may reduce
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33 116 sedentary behaviours. However, physical activity data was collected using direct
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35 117 observation during the school day, only. This limits the ability to examine carry over
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37 118 effects outside the school environment (ie, at weekends and during evenings). Taken
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39 119 together, the emerging evidence suggests that the physical environment could play an
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41 120 important role in children's physical activity behaviour, but more robust evidence is
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43 121 required.
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3 124 **SETTING**
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6 125 Camden Borough Council is re-designing seven existing school playgrounds (five primary schools
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8 126 and two secondary schools), that are thought not to be conducive to physical activity/ active play,
9
10 127 with exciting bespoke features to engage children to become more active. Each school will receive
11
12 128 a unique playground design, for example displayed in Figure 1. Example features include new
13
14 129 Astroturf games pitches, climbing frames, trampolines, monkey bars, and outdoor gyms, which
15
16 130 have been designed based on themes (eg, ancient ruins, volcanoes, clouds etc.) emerging from
17
18 131 qualitative work with children and teachers in each school. The research team did not carry out
19
20 132 the qualitative work nor did they provide input into the design of the playgrounds. Camden
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24 133 Council's underlying goal is to encourage participation by creating opportunities for physical
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26 134 activity outside of traditional sports or team competition. This presents a unique
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28 135 opportunity to evaluate the impact of these structures on children's physical activity, health
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30 136 and wellbeing outcomes while addressing previous limitations in the literature (ie, collecting
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32 137 activity only in school).
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39 139 We hypothesise that the new play grounds will increase young peoples' time spent in both light
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41 140 and moderate-to-vigorous physical activity and reduce sedentary behaviour during break time,
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43 141 and consequently improve levels of general fitness (eg, grip and leg strength, peak flow and
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45 142 adiposity).
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52 144 **AIMS**
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55 145 The *Camden Active Spaces* project **consists** of two key elements; 1) redesign of the school
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57 146 playgrounds; 2) evaluation of the hypothesised benefits. In the present paper we focus on
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3 147 the evaluation only. Thus, the primary aim of this project is to evaluate the impact of the re-
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5 148 designed playgrounds on children's physical activity, wellbeing, engagement, and physical
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7 149 function/fitness.
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12 13 14 151 **METHOD AND ANALYSES**

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17 152 The evaluation of *Camden Active Spaces* will use a longitudinal quasi-experimental design.
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19 153 Baseline data collection will take place in the Spring/Summer term 2014, follow-up I data
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21 154 collection will take place during the Autumn term 2014, and follow-up II during the Summer
22
23 155 term of 2015 (see Figure 2). Between baseline and follow-up I (school summer holidays) the
24
25 156 school playgrounds will be re-designed. A second follow-up will allow us to investigate if
26
27 157 short-term effects of the intervention (if they exist) are sustained over a longer period. This
28
29 158 evaluation has been funded by the Economic and Social Research Council, UK
30
31 159 (ES/M003795/1), whilst the core project (playground redesign) has been funded by Camden
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33 160 Clinical Commissioning Group and London Borough of Camden. Ethical approval was
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35 161 granted by the University College London Research Ethics Committee (4400/002).
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43 44 163 **Inclusion criteria**

45 46 47 164 *School inclusion criteria*

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50 165 Seven schools located in the London Borough of Camden have been selected to receive the
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52 166 re-designed playgrounds and all seven schools have agreed to take part in the study.
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3 168 In addition to the seven experimental schools one control school will be recruited into the study.
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5 169 This school will be located in the London Borough of Camden and it will not be receiving a new
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7 170 playground design, moreover, it will not differ from experimental schools based on student
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9 171 demographics or school policy. Owing to resources it is only feasible to collect data from a single
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11 172 control school. The authors acknowledge that an equal number of controls to experimental
12
13 173 schools would allow for a more robust experimental design.

174 *Participant Inclusion criteria*

175 We aim to randomly select approximately 100 children (see below power calculation) evenly
176 distributed across school year groups (aged 5 to 11 years in primary school and aged 11 to
177 16 years in secondary school) from each of the eight schools (total sample size 800).
178 Children aged 17 to 18 years or any school leavers in 2014 will not be asked to participate in
179 the current project, owing to time table restrictions due to final exams and potential loss to
180 follow up. Students whose parents have not opted them out of the study will be eligible to
181 participate (see section Ethics and Dissemination for details on obtaining consent).

182

183 **Recruitment**

184 The seven schools who will be receiving the redesigned playgrounds have previously been
185 recruited into the study by Camden Borough Council. To recruit children into the study
186 presentations will be given to each year group within each school, during assemblies. The
187 presentations will disseminate information on *Camden Active Spaces*, what would be
188 involved if children were to take part in the study and benefits of the study to children and
189 the school. At the end of the presentations children will be given participant study
190 information sheets. In order to make parents aware of the study a parent information sheet

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3 191 will be emailed to all parents (translated into different languages where required), posted
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5 192 on the school webpage, in addition to hard copies being made available at the school. In an
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7 193 attempt to maximise response rates and adherence to protocol, each child who completes
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9 194 the wear protocol will be awarded a one-month free swimming voucher and entered into a
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11 195 prize draw to win an iPod Touch (one iPod Touch will be awarded per school). All schools
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13 196 taking part in the study will be entered into a separate prize draw to win one of two
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15 197 Nintendo Wiis.
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24 199 **Procedures**

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26 200 Data collection procedures will take place over a period of **12 months**. A team of trained
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28 201 researchers will collect data from each school on a date and time that is convenient for the
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30 202 school. Children will be invited to take part in data collection. Data collection sessions will
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32 203 last approximately 30 minutes. A series of fitness tests and anthropometric measurements
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34 204 will be carried out on children, in an appropriate room in the school (e.g. sports or assembly
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36 205 hall). Once fitness tests and anthropometric measurements have been completed objective
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38 206 devices (accelerometers) will be given to children to monitor their physical activity
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40 207 behaviour. Between four and seven days of accelerometer data are needed to provide a
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42 208 reliable estimate of habitual physical activity.[17] Thus participants will be asked to wear
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44 209 objective devices for 7 consecutive days. On day seven participants will return the device to
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46 210 research staff at the school where they will then complete a questionnaire on their physical
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48 211 activity behaviour. This exact process will be repeated at follow-up I and follow-up II.
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3 213 **Measurement and instruments**
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6 214 *Accelerometer*
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9 215 It is now recognised that accelerometers provide the most reliable and valid measurement
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11 216 of activity in children [16] and are considered the gold standard approach. These wearable
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13 217 motion sensors measure movement across three dimensions, thus providing minute-by-
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15 218 minute time-stamped data on activity intensity, duration, and patterns across the day.
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19 219 Objective physical activity monitoring has been successfully used in similar study settings to
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21 220 the present project.[14,18, 19]
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24 221 The present evaluation will use the Actigraph GT3X accelerometer. This device is validated
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26 222 and has been used in other studies with primary and high school children (see for example:
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28 223 www.iconnect.co.uk and <http://www.cedar.iph.cam.ac.uk/research/directory/speedy/>). The
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31 224 Actigraph GT3X is worn on a belt around the waist with the device itself positioned above
32
33 225 the right hip either over or under clothing. **We will employ a sampling frequency of 30 hz.**
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36 226 Children will be asked to wear the device during waking hours every day for seven
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38 227 consecutive days, but not during water-based activities or sleep.
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45 229 *Fitness Tests*
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48 230 A series of fitness tests will be carried out, following Standard Operating Procedure Forms,
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50 231 on all children taking part in the study. These tests have been extensively validated and used
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52 232 in previous cohort studies of children (eg, <http://www.chasestudy.ac.uk/study->
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54 233 measurement) Four fitness tests will be carried out to measure aspects of general fitness:
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56 234 participants will be asked to perform the hand held Dynamometer test to assess grip
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3 235 strength, the standing horizontal jump test to assess leg power, the peak flow test to assess
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5 236 lung function, and the sit-and-reach test to assess flexibility. Participants' weight and body
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8 237 composition will be measured using the Tanita SC-330 Body Composition Analyser (Tanita
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10 238 Inc, IL, USA) and height will be measured using the Leicester Height Measure, from which
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12 239 BMI will be calculated kg/m^2 .

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19 241 *Questionnaires*

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22 242 All children taking part in the study will be asked to complete a questionnaire. The
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24 243 questionnaire will take approximately ten minutes to complete and includes questions on
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26 244 standard demographics and physical activity, as well as potentially important correlates of
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28 245 physical activity. **Teaching assistants and research staff will assist all children in completing**
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31 246 **questionnaires.**

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34 247 **The Girls Health Enrichment Multi-Studies (GEMS) physical activity survey has been**
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36 248 **embedded within the questionnaire to give a subjective measure of physical activity and**
37
38 249 **provide an understanding of which specific physical activity behaviours are influenced by**
39
40 250 **the playground redesign, if any.** GEMS has validity and reliability equivalent to other self-
41
42 251 report measures of physical activity [20] and was deemed suitable for both primary and high
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44 252 school boys and girls by those who designed the present study, owing to its simplicity. The
45
46 253 questionnaire also includes items on travel mode (as used in the iConnect Study;
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48 254 www.iconnect.co.uk).

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51 255 **Teachers will be asked to complete the validated Strengths and Difficulties**
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54 256 **questionnaire;[21] this questionnaire provides a measure of children's behaviour, mental**

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3 257 health, engagement and well-being and takes approximately five minutes to complete per
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5 258 child.
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9 259 Each school has one Head Teacher. Head Teachers (n=8) will be asked to complete a
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11 260 questionnaire to allow for an understanding of differences between schools on
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13 261 "playground policy." Questions include, "During what type of weather are children not
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15 262 allowed to go outside during scheduled breaks (i.e. rain/ snow)?" "Are any sections of the
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17 263 current playground out of use during bad weather (i.e. school field when raining), if yes
18
19 264 please specify?" "When children cannot go outside on scheduled breaks, owing to bad
20
21 265 weather, where do they spend their break?" and "Are there any current
22
23 266 initiatives/programs to promote physical activity and/or healthy lifestyles in your school,
24
25 267 if yes please specify?" Head teachers will be asked to complete an identical survey at
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29 268 follow-up to allow for the assessment of changes in "playground policy" between each
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31 269 time point.
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271 ANALYSIS

272 Outcome

273 The primary outcome for this study will be change in average daily time spent in MVPA as
274 recorded by the Actigraph accelerometer. In addition the study has been designed to collect
275 the following secondary outcomes using participant questionnaires and objective measures
276 (1) change in average daily time spent sedentary, (2) change in average daily time spent in
277 light and vigorous activity at different times of the day (playtimes at school, leisure time at

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3 278 home), (3) change in peak flow, sit-and-reach, grip strength, standing horizontal jump, and
4
5 279 body mass index (BMI)/body composition, **(4) change in Strength and Difficulties scores.**
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11 281 *Quantitative analysis*

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14 282 Raw data files will be extracted from each Actigraph device and processed using bespoke
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16
17 283 software (Actilife) to quantify a range of features that will directly contribute to the
18
19 284 determination of active and sedentary time. **We intend to follow methods used in the**
20
21
22 285 **International Children's Accelerometry Database study that incorporated children aged 4-**
23
24 286 **18 yrs old [2]. Briefly, data files will be reintegrated to a 60-second epoch and non-wear**
25
26 287 **time defined as 60 minutes of consecutive zeros, allowing for 2 minutes of non-zero**
27
28 288 **interruptions. All children with at least 1 day with at least 500 minutes of measured**
29
30 289 **monitor wear time between 7 AM and midnight will be included. Total physical activity**
31
32 290 **will be expressed as total counts, including sedentary minutes, divided by measured time**
33
34 291 **per day (counts/min, cpm). Time spent sedentary will be defined as all minutes showing**
35
36 292 **less than 100 cpm and MVPA time as minutes showing more than 3000 cpm.** Multilevel
37
38 293 modelling will be used to analyse the data. This approach offers several advantages over
39
40 294 simple regression models. We will be able to model changes in activity over the three
41
42 295 assessment periods accounting for the inter-individual as well as intra-individual differences.
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51 297 *Sample size*

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55 298 A previous school based intervention to examine the effects of changes in playground
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57 299 structure on physical activity [18] demonstrated a small effect size ($d = 0.10$). Thus, based on
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3 300 these data, a sample size of N=458 would provide us with 80% power at 5% significance
4
5 301 level to detect small differences in moderate intensity physical activity using a repeated
6
7 302 measures design (calculated using G-Power). We will aim to recruit 100 children from each
8
9
10 303 school to allow for dropout and incomplete Actigraph data.
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17 305 **ETHICAL CONSIDERATION AND DISSEMINATION**
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20 306 Firstly, head teachers from each school will be asked to provide explicit written consent for
21
22 307 their schools and school children to take part in the study. Next, if parents **(of primary and**
23
24 308 **secondary school children)** do not want their child(ren) to take part in the study they will be
25
26
27 309 given the option to “opt-out” their child(ren), instructions to parents on how to opt-out
28
29 310 their child(ren) are provided in the parent study information sheet. Prior to data collection
30
31 311 all high school (not primary school) children will be asked to provide explicit written assent.
32
33

34
35 312 The findings from this study will be disseminated to academic researchers and to
36
37 313 policymakers through several mechanisms. First, we will employ the usual avenues for
38
39 314 dissemination of academic research, including conference presentations and journal
40
41 315 articles. Second, we will disseminate this research via social media outlets such as the
42
43 316 University College London – Physical Activity Research Group Twitter account. Third, with
44
45 317 Camden Council, we will include this physical activity study within the regular programme of
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47 318 briefings that are presented to government departments interested in physical activity,
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49 319 including the Department of Health, the Department for Communities and Local
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51 320 Government, etc.
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3 322 **Competing interests**
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6 323 The authors declare that they have no competing interests.
7
8

9 324 **Funding**
10

11
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13
14

15 326 **Authors' contributions**
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17
18 327 Lee Smith, Courtney Kipps, Daniel Aggio, Paul Fox, Nigel Robinson, Verena Trend, Suzie
19

20 328 Munnery, Barry Kelly, and Mark Hamer made substantial contribution to the concept and
21

22 329 design of the study. Lee Smith drafted the manuscript and Courtney Kipps, Daniel Aggio,
23

24 330 Paul Fox, Nigel Robinson, Verena Trend, Suzie Munnery, Barry Kelly, and Mark Hamer
25

26 331 revised it critically for important intellectual content. Lee Smith, Courtney Kipps, Daniel
27

28 332 Aggio, Paul Fox, Nigel Robinson, Verena Trend, Suzie Munnery, Barry Kelly, and Mark Hamer
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30 333 approved the final version of the manuscript to be published.
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40 336 **Figure Legends**
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43 337 **Figure 1: Example of new playground designs**
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46 338 **Figure 2: Overview of study design**
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Figure 1: Example of new playground designs

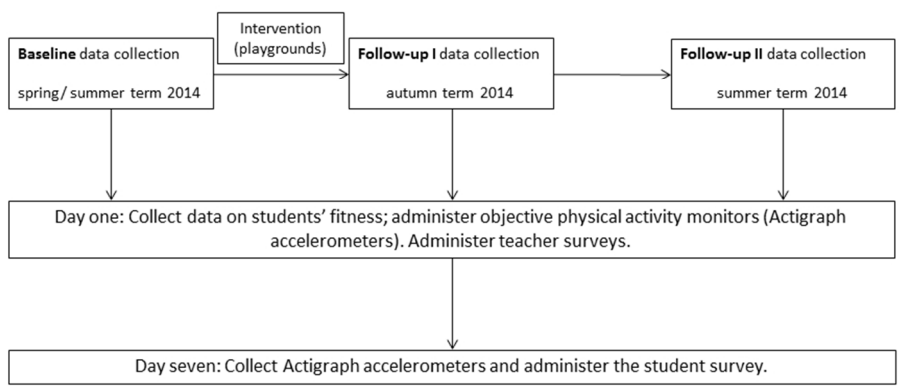


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Figure Two: Overview of study design



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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract YES
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found YES
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported YES
Objectives	3	State specific objectives, including any prespecified hypotheses YES
Methods		
Study design	4	Present key elements of study design early in the paper YES
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection YES
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up YES
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants YES
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable YES
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group YES
Bias	9	Describe any efforts to address potential sources of bias YES
Study size	10	Explain how the study size was arrived at YES
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why YES

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2	Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding
3			YES
4			_____
5			(b) Describe any methods used to examine subgroups and interactions
6			NA
7			_____
8			(c) Explain how missing data were addressed
9			NA
10			_____
11			(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed
12			<i>Case-control study</i> —If applicable, explain how matching of cases and controls was
13			addressed
14			<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of
15			sampling strategy
16			NA
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18			(e) Describe any sensitivity analyses

Continued on next page

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60**Results**

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	NA
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	NA
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	YES
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	NA
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	NA
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	NA
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	NA
		(b) Report category boundaries when continuous variables were categorized	NA
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	NA
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	YES
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	NA
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA

Other information

Funding 22 Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

YES

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Camden Active Spaces: Does the Construction of Active School Playgrounds Influence Children's Physical Activity Levels? A Longitudinal Quasi-Experiment Protocol

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Complete List of Authors:	Smith, Lee; University College London, Epidemiology and Public Health Kipps, Courtney; University College London Hospital, Institute of Sport, Exercise and Health Aggio, Daniel; University College London, Epidemiology and Public Health Fox, Paul; Camden Borough Council, Robinson, Nigel; Camden Borough Council, Trend, Verena; Camden Borough Council, Munnery, Suzie; Camden Borough Council, Kelly, Barry; Camden and Islington Public Health, Hamer, Mark; University College London, Epidemiology and Public Health
Primary Subject Heading:	Public health
Secondary Subject Heading:	Paediatrics
Keywords:	PREVENTIVE MEDICINE, PUBLIC HEALTH, SPORTS MEDICINE

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**Camden Active Spaces: Does the Construction of Active School Playgrounds Influence
Children's Physical Activity Levels? A Longitudinal Quasi-Experiment Protocol**

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5 Lee Smith*, Health Behaviour Research Centre, Department of Epidemiology and Public
6 Health, University College London, London, UK, WC1E 6BT; lee.smith@ucl.ac.uk; 020 7679
7 1812

8 Courtney Kipps, Institute Sport Exercise and Health, University College London Hospital,
9 London, UK

10 Daniel Aggio, Physical Activity Research Group, Department of Epidemiology and Public
11 Health, London, UK

12 Paul Fox, Camden Borough Council, London, UK

13 Nigel Robinson, Camden Borough Council, London, UK

14 Verena Trend, Camden Borough Council, London, UK

15 Suzie Munnery, Camden Borough Council, London, UK

16 Barry Kelly, Camden and Islington Public Health, London, UK

17 Mark Hamer, Physical Activity Research Group, Department of Epidemiology and Public
18 Health, London, UK

19 *Corresponding author

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3 20 **Key words: physical activity/ active play/ children/ school/ environment**
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56 39 **INTRODUCTION**
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9 40 Physical activity is essential for every facet of children's health. However, physical activity
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11 41 levels in British children are low. The school environment is a promising setting to increase
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13 42 children's physical activity but limited empirical evidence exists on how a change in the
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15 43 outdoor physical school environment influences physical activity behaviour. London
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17 44 Borough of Camden is re-designing seven existing school playgrounds to engage children to
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19 45 become more physically active.
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24 46 The primary aim of this project is to evaluate the impact of the re-designed playgrounds on
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26 47 children's physical activity, wellbeing, and physical function/fitness.
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3132 49 **METHOD AND ANALYSIS**
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36 50 This project will use a longitudinal quasi-experimental design. Seven experimental schools
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38 51 and one control school will take part. One baseline data collection session and two follow-
39
40 52 ups will be carried out. Between baseline and follow-up the experimental school
41
42 53 playgrounds will be re-designed. At baseline, a series of fitness tests, anthropometric and
43
44 54 questionnaire measurements, and 7 day objective physical activity monitoring (Actigraph
45
46 55 accelerometer) will be carried out on children (aged 5 to 16 years). This will be repeated at
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48 56 follow-up. Changes in overall physical activity levels and levels during different times of the
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50 57 day (eg, school breaks) will be examined. Multilevel regression modelling will be used to
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52 58 analyse the data.
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61 ETHICS AND DISSEMINATION

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9 62 The results of this study will be disseminated through peer-review publications and scientific
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11 63 presentations. Ethical approval was obtained through the University College London
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14 64 Research Ethics Committee (Reference number: 4400/002).
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79 **INTRODUCTION**

80 Physical activity is essential for every facet of children's (aged 5 to 16 years) health. For
81 example, higher levels of physical activity in children are associated with more favourable
82 cardiovascular disease risk factors whereas excessive levels of sedentary behaviour have the
83 reverse effect.[1,2] Physical activity can also benefit psychological health by aiding in the
84 prevention of anxiety and depressive symptoms and contributing to the improvement of
85 self-esteem.[3] Importantly, rather than detracting from learning, more physical activity and
86 breaks from sitting in school are thought to enhance cognitive function and academic
87 performance.[4] It is also more likely that active children will become active adults, since
88 some tracking of physical activity behaviour has been observed from childhood to
89 adulthood.[5] However, in westernised countries current levels of physical activity in
90 children are low as there are increasing opportunities to participate in sedentary
91 activities.[6,7] For example, it is recommended that children engage in physical activity of
92 moderate intensity for at least one hour a day, to maintain good health.[8] However, just
93 24% of British girls and 32% of boys achieve this recommendation.[7] Physical inactivity is
94 estimated to cost the NHS approximately £8 billion per year in health care costs alone.[8]
95 Encouraging physically active lifestyles in children is therefore crucial in nurturing a healthy
96 future generation of adults.

97 A recent meta-analysis found that the effects of interventions to increase physical activity in
98 children have been, at best, modest, and concluded that alternative approaches are
99 required.[9] In the UK, children spend approximately 60% of their weekday in school where
100 physical activity levels, particularly in girls, are low.[10,11] Environments both facilitate and

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3 101 provide the arena for physical activity [12]. Interventions that target the school environment
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5 102 may offer great opportunity to increase physical activity levels. However, there is little
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7 103 robust empirical evidence concerning the effect of changing the physical environment on
8
9 104 activity levels in children. Emerging data has suggested that a positive perception of the
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11 105 school play environment was associated with higher levels of moderate-vigorous physical
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13 106 activity (MVPA) during playtime.[13] Moreover, the number of permanent play facilities in
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15 107 school playgrounds has been found to be associated with higher physical activity levels.[14]
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17 108 A recent review [15] on the value of playgrounds for children’s physical activity identified 13
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19 109 experimental studies, which have produced mixed findings, likely owing to differences in
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21 110 intervention design. For example, the review identified that reducing playground density
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23 111 increased physical activity levels, but the provision of play equipment produced mixed
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25 112 effects, whereas no effects were found on the provision of playground markings and
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27 113 promotion of physical activity by teachers. Just one study investigated the impact of “major”
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29 114 playground reconstruction on children’s physical activity behaviour [16] and concluded
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31 115 renovated schoolyards to promote physical activity may increase the number of children
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33 116 who are physically active and may reduce sedentary behaviours. However, physical activity
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35 117 data was collected using direct observation during the school day, only. This limits the ability
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37 118 to examine carry over effects outside the school environment (ie, at weekends and during
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39 119 evenings). Taken together, the emerging evidence suggests that the physical environment
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41 120 could play an important role in children’s physical activity behaviour, but more robust
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3 123 Increasing physical activity levels is well established as a way to improve fitness and health
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5 124 outcomes in young people. Strong's et al. [1] review identified 17 experimental studies that
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7 125 aimed to increase levels of physical activity, and these all found improvements in aerobic
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10 126 fitness. Two experimental studies implemented programs of moderately intense exercise 30
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12 127 to 60 minutes in duration, 3 to 7 days per week, and this led to a reduction in total body
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14 128 adiposity in overweight young people. Interestingly, the review also identified three
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17 129 longitudinal and two experimental studies in young people that showed physical activity or
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20 130 strength training improved muscular strength and endurance. It is plausible to assume that
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22 131 an increase in movement and a decrease in sedentary behaviour may result in an increase in
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24 132 hamstring flexibility. This is important as maintaining hamstring flexibility may prevent acute
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26
27 133 and chronic musculoskeletal injuries.[17] There is also evidence that physical activity is
28
29 134 associated with scores on a scale (The Strengths and Difficulties Questionnaire) measuring
30
31 135 mental wellbeing (eg, happiness, behaviour, concentration, self-esteem etc).[18] On this
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34 136 basis we hypothesise that a change in the physical school playground environment which
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36 137 increases levels of physical activity or reduces sedentary behaviour should subsequently
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38 138 improve fitness and health outcomes.

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45 140 A recent study found that engaging in 40% of moderate-intensity physical activity during
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47 141 school playtime equated to 34 minutes of daily MVPA.[19] This exceeds the *minimum*
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49 142 recommendation of 30 minutes of at least moderate-intensity physical activity for children's
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51 143 good health.[20] It has been suggested that this guideline is a realistic target for children to
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54 144 achieve during school playtime,[21] especially if a playground has been modified to
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57 145 encourage physical activity.

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6 147 **SETTING**
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9 148 Camden Borough Council is re-designing seven existing school playgrounds (five primary schools and
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11 149 two secondary schools), that are thought not to be conducive to physical activity/ active play, with
12
13 150 exciting bespoke features to engage children to become more active. Each school will receive a
14
15 151 unique playground design, for example displayed in Figure 1. Example features include new
16
17 152 Astroturf games pitches, climbing frames, trampolines, monkey bars, and outdoor gyms, which have
18
19 153 been designed based on themes (eg, ancient ruins, volcanoes, clouds etc.) emerging from qualitative
20
21 154 work with children and teachers in each school. The research team did not carry out the qualitative
22
23 155 work nor did they provide input into the design of the playgrounds. The qualitative work and the
24
25 156 design of the playgrounds were carried out by two private organisations specialising in playground
26
27 157 design. Camden Council's underlying goal is to encourage participation by creating
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29 158 opportunities for physical activity outside of traditional sports or team competition. This
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31 159 presents a unique opportunity to evaluate the impact of these structures on children's
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33 160 physical activity, health and wellbeing outcomes while addressing previous limitations in the
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35 161 literature (ie, collecting activity only in school).
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163 We hypothesise that the new play grounds will increase young peoples' time spent in both light and
164 moderate-to-vigorous physical activity and reduce sedentary behaviour during break time, and
165 consequently improve levels of general fitness (eg, grip and leg strength, peak flow and adiposity).
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56 167 **AIMS**
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3 168 The *Camden Active Spaces* project consists of two key elements; 1) redesign of the school
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5 169 playgrounds; 2) evaluation of the hypothesised benefits. In the present paper we focus on
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7
8 170 the evaluation only. Thus, the primary aim of this project is to evaluate the impact of the re-
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10 171 designed playgrounds on children's physical activity, wellbeing, and physical
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12 172 function/fitness.
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19 174 **METHOD AND ANALYSES**

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22 175 The evaluation of *Camden Active Spaces* will use a longitudinal quasi-experimental design.
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24 176 Baseline data collection will take place in the Spring/Summer term 2014, follow-up I data
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26 177 collection will take place during the Autumn term 2014, and follow-up II during the Summer
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28 178 term of 2015 (see Figure 2). Between baseline and follow-up I (school summer holidays) the
29
30 179 school playgrounds will be re-designed. A second follow-up will allow us to investigate if
31
32 180 short-term effects of the intervention (if they exist) are sustained over a longer period. This
33
34 181 evaluation has been funded by the Economic and Social Research Council, UK
35
36 182 (ES/M003795/1), whilst the core project (playground redesign) has been funded by Camden
37
38 183 Clinical Commissioning Group and London Borough of Camden. Ethical approval was
39
40 184 granted by the University College London Research Ethics Committee (4400/002).
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49 186 **Inclusion criteria**

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52 187 *School inclusion criteria*
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3 188 Seven schools located in the London Borough of Camden have been selected to receive the
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5 189 re-designed playgrounds and all seven schools have agreed to take part in the study.
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11 191 In addition to the seven experimental schools one control school will be recruited into the study.
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13 192 This school will be located in the London Borough of Camden and it will not be receiving a new
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15 193 playground design, moreover, it will not differ from experimental schools based on student
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17 194 demographics or school policy. Owing to resources it is only feasible to collect data from a single
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19 195 control school. The authors acknowledge that an equal number of controls to experimental schools
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21 196 would allow for a more robust experimental design.
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25 197 *Participant Inclusion criteria*
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28 198 We aim to randomly select approximately 100 children (see below power calculation) evenly
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30 199 distributed across school year groups (aged 5 to 11 years in primary school and aged 11 to
31
32 200 16 years in secondary school) from each of the eight schools (total sample size 800).
33
34 201 Children aged 17 to 18 years or any school leavers in 2014 will not be asked to participate in
35
36 202 the current project, owing to time table restrictions due to final exams and potential loss to
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38 203 follow up. Students whose parents have not opted them out of the study will be eligible to
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40 204 participate (see section Ethics and Dissemination for details on obtaining consent).
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49 206 **Recruitment**
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52 207 The seven schools who will be receiving the redesigned playgrounds have previously been
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54 208 recruited into the study by Camden Borough Council. To recruit children into the study
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56 209 presentations will be given to each year group within each school, during assemblies. The
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3 210 presentations will disseminate information on *Camden Active Spaces*, what would be
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5 211 involved if children were to take part in the study and benefits of the study to children and
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7 212 the school. At the end of the presentations children will be given participant study
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10 213 information sheets. In order to make parents aware of the study a parent information sheet
11
12 214 will be emailed to all parents (translated into different languages where required), posted
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14 215 on the school webpage, in addition to hard copies being made available at the school. In an
15
16 216 attempt to maximise response rates and adherence to protocol, each child who completes
17
18 217 the wear protocol will be awarded a one-month free swimming voucher and entered into a
19
20 218 prize draw to win an iPod Touch (one iPod Touch will be awarded per school). All schools
21
22 219 taking part in the study will be entered into a separate prize draw to win one of two
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26 220 Nintendo Wiis.

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33 222 **Procedures**

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36 223 Data collection procedures will take place over a period of 12 months. A team of trained
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38 224 researchers will collect data from each school on a date and time that is convenient for the
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40 225 school. Children will be invited to take part in data collection. Data collection sessions will
41
42 226 last approximately 30 minutes. A series of fitness tests and anthropometric measurements
43
44 227 will be carried out on children, in an appropriate room in the school (e.g. sports or assembly
45
46 228 hall). Once fitness tests and anthropometric measurements have been completed objective
47
48 229 devices (accelerometers) will be given to children to monitor their physical activity
49
50 230 behaviour. Between four and seven days of accelerometer data are needed to provide a
51
52 231 reliable estimate of habitual physical activity.[22] Thus participants will be asked to wear
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55 232 objective devices for 7 consecutive days. On day seven participants will return the device to
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3 233 research staff at the school where they will then complete a questionnaire on their physical
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5 234 activity behaviour. This exact process will be repeated at follow-up I and follow-up II.
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13 14 15 236 **Measurement and instruments**

16 17 237 *Accelerometer*

18 238 It is now recognised that accelerometers provide the most reliable and valid measurement
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20 239 of activity in children [16] and are considered the gold standard approach. These wearable
21
22 240 motion sensors measure movement across three dimensions, thus providing minute-by-
23
24 241 minute time-stamped data on activity intensity, duration, and patterns across the day.

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26 242 Objective physical activity monitoring has been successfully used in similar study settings to
27
28 243 the present project.[14,23, 24]

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30 244 The present evaluation will use the Actigraph GT3X accelerometer. This device is validated
31
32 245 and has been used in other studies with primary and high school children (see for example:
33
34 246 www.iconnect.co.uk and <http://www.cedar.iph.cam.ac.uk/research/directory/speedy/>). The

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36 247 Actigraph GT3X is worn on a belt around the waist with the device itself positioned above
37
38 248 the right hip either over or under clothing. We will employ a sampling frequency of 30 hz.

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40 249 Children will be asked to wear the device during waking hours every day for seven
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42 250 consecutive days, but not during water-based activities or sleep.
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51 52 53 252 *Fitness Tests*

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3 253 A series of fitness tests will be carried out, following Standard Operating Procedure Forms,
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5 254 on all children taking part in the study. Four fitness tests will be carried out to measure
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7 255 aspects of general fitness: participants will be asked to perform the hand held
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10 256 Dynamometer test to assess grip strength, the standing horizontal jump test to assess leg
11
12 257 power, the peak flow test to assess lung function, and the sit-and-reach test to assess
13
14 258 flexibility. Participants' weight and body composition will be measured using the Tanita SC-
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16
17 259 330 Body Composition Analyser (Tanita Inc, IL, USA) and height will be measured using the
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19 260 Leicester Height Measure, from which BMI will be calculated kg/m^2 . These tests have been
20
21 261 extensively used in previous cohort studies of young people (eg,
22
23 262 <http://www.chasestudy.ac.uk/study-measurement>) and have shown good validity and
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25 263 reliability in young people across broad age groups (<http://www.chasestudy.ac.uk/study->
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27 264 measurement). [25-27]
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35 266 *Questionnaires*

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38 267 All children taking part in the study will be asked to complete a questionnaire. The
39
40 268 questionnaire will take approximately ten minutes to complete and includes questions on
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42 269 standard demographics and physical activity, as well as potentially important correlates of
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44 270 physical activity. Teaching assistants and research staff will assist all children in completing
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46 271 questionnaires.
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51 272 The Girls Health Enrichment Multi-Studies (GEMS) physical activity survey has been
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53 273 embedded within the questionnaire to give a subjective measure of physical activity and
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55 274 provide an understanding of which specific physical activity behaviours are influenced by
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3 275 the playground redesign, if any. GEMS has validity and reliability equivalent to other self-
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5 276 report measures of physical activity [28] and was deemed suitable for both primary and high
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7 277 school boys and girls by those who designed the present study, owing to its simplicity. The
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10 278 questionnaire also includes items on travel mode (as used in the iConnect Study;
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12 279 www.iconnect.co.uk).

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15 280 Teachers will be asked to complete the validated Strengths and Difficulties
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17 281 questionnaire;[29] this questionnaire provides a measure of children's behaviour, mental
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19 282 health, engagement and well-being and takes approximately five minutes to complete per
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21 283 child.

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26 284 Each school has one Head Teacher. Head Teachers (n=8) will be asked to complete a
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28 285 questionnaire to allow for an understanding of differences between schools on "playground
29
30 286 policy." Questions include, "During what type of weather are children not allowed to go
31
32 287 outside during scheduled breaks (i.e. rain/ snow)?" "Are any sections of the current
33
34 288 playground out of use during bad weather (i.e. school field when raining), if yes please
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36 289 specify?" "When children cannot go outside on scheduled breaks, owing to bad weather,
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38 290 where do they spend their break?" and "Are there any current initiatives/programs to
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40 291 promote physical activity and/or healthy lifestyles in your school, if yes please specify?"
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44 292 Head teachers will be asked to complete an identical survey at follow-up to allow for the
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46 293 assessment of changes in "playground policy" between each time point.

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53 295 **ANALYSIS**

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56 296 *Outcome*
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3 297 The primary outcome for this study will be change in average daily time spent in MVPA as
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5 298 recorded by the Actigraph accelerometer. In addition the study has been designed to collect
6
7 299 the following secondary outcomes using participant questionnaires and objective measures
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10 300 (1) change in average daily time spent sedentary, (2) change in average daily time spent in
11
12 301 light and vigorous activity at different times of the day (playtimes at school, leisure time at
13
14 302 home), (3) change in peak flow, sit-and-reach, grip strength, standing horizontal jump, and
15
16 303 body mass index (BMI)/body composition, (4) change in Strength and Difficulties scores.
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23 305 *Quantitative analysis*

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26 306 Raw data files will be extracted from each Actigraph device and processed using bespoke
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28 307 software (Actilife) to quantify a range of features that will directly contribute to the
29
30 308 determination of active and sedentary time. We intend to follow methods used in the
31
32 309 International Children's Accelerometry Database study that incorporated children aged 4-18
33
34 310 yrs old [2]. Briefly, data files will be reintegrated to a 60-second epoch and non-wear time
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36 311 defined as 60 minutes of consecutive zeros, allowing for 2 minutes of non-zero
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38 312 interruptions. All children with at least 1 day with at least 500 minutes of measured monitor
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40 313 wear time between 7 AM and midnight will be included. Total physical activity will be
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42 314 expressed as total counts, including sedentary minutes, divided by measured time per day
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44 315 (counts/min, cpm). Time spent sedentary will be defined as all minutes showing less than
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46 316 100 cpm and MVPA time as minutes showing more than 3000 cpm. Multilevel modelling will
47
48 317 be used to analyse the data. This approach offers several advantages over simple regression
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50 318 models. We will be able to model changes in activity over the three assessment periods
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52 319 accounting for the inter-individual as well as intra-individual differences.
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7 321 *Sample size*

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10 322 A previous school based intervention to examine the effects of changes in playground
11 323 structure on physical activity [23] demonstrated a small effect size ($d = 0.10$). Thus, based on
12 324 these data, a sample size of $N=458$ would provide us with 80% power at 5% significance
13 325 level to detect small differences in moderate intensity physical activity using a repeated
14 326 measures design (calculated using G-Power). We will aim to recruit 100 children from each
15 327 school to allow for dropout and incomplete Actigraph data.
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29 329 **LIMITATIONS**

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31 331 It is not possible to carry out a multicentre cluster randomised-controlled-trial. Key limitations of this
32 332 study include a quasi-experimental design with non-randomly selected control participants and the
33 333 recruitment of one control school.
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44 335 **ETHICAL CONSIDERATION AND DISSEMINATION**

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46 336 Firstly, head teachers from each school will be asked to provide explicit written consent for
47 337 their schools and school children to take part in the study. Next, if parents (of primary and
48 338 secondary school children) do not want their child(ren) to take part in the study they will be
49 339 given the option to “opt-out” their child(ren), instructions to parents on how to opt-out
50 340 their child(ren) are provided in the parent study information sheet. Prior to data collection
51 341 all high school (not primary school) children will be asked to provide explicit written assent.
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3 342 The findings from this study will be disseminated to academic researchers and to
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5 343 policymakers through several mechanisms. First, we will employ the usual avenues for
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7 344 dissemination of academic research, including conference presentations and journal
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9 345 articles. Second, we will disseminate this research via social media outlets such as the
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11 346 University College London – Physical Activity Research Group Twitter account. Third, with
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13 347 Camden Council, we will include this physical activity study within the regular programme of
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15 348 briefings that are presented to government departments interested in physical activity,
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17 349 including the Department of Health, the Department for Communities and Local
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19 350 Government, etc.
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28 352 **Competing interests**

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31 353 The authors declare that they have no competing interests.
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33

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35
36
37 355 This work was supported by The Economic and Social Research Council, UK (ES/M003795/1)
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40 356 **Authors' contributions**

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42
43 357 Lee Smith, Courtney Kipps, Daniel Aggio, Paul Fox, Nigel Robinson, Verena Trend, Suzie
44
45 358 Munnery, Barry Kelly, and Mark Hamer made substantial contribution to the concept and
46
47 359 design of the study. Lee Smith drafted the manuscript and Courtney Kipps, Daniel Aggio,
48
49 360 Paul Fox, Nigel Robinson, Verena Trend, Suzie Munnery, Barry Kelly, and Mark Hamer
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51 361 revised it critically for important intellectual content. Lee Smith, Courtney Kipps, Daniel
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3 362 Aggio, Paul Fox, Nigel Robinson, Verena Trend, Suzie Munnery, Barry Kelly, and Mark Hamer
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5 363 approved the final version of the manuscript to be published.
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40 435 **Figure Legends**41 436 **Figure 1: Example of new playground designs**42 437 **Figure 2: Overview of study design**

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3 1 **Camden Active Spaces: Does the Construction of Active School Playgrounds Influence**
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5 2 **Children's Physical Activity Levels? A Longitudinal Quasi-Experiment Protocol**
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11 4 Lee Smith*, Health Behaviour Research Centre, Department of Epidemiology and Public
12
13 5 Health, University College London, London, UK, WC1E 6BT; lee.smith@ucl.ac.uk; 020 7679
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18
19 7 Courtney Kipps, Institute Sport Exercise and Health, University College London Hospital,
20
21 8 London, UK
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25 9 Daniel Aggio, Physical Activity Research Group, Department of Epidemiology and Public
26
27 10 Health, London, UK
28
29

30
31 11 Paul Fox, Camden Borough Council, London, UK
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35 12 Nigel Robinson, Camden Borough Council, London, UK
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39 13 Verena Trend, Camden Borough Council, London, UK
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43 14 Suzie Munnery, Camden Borough Council, London, Uk
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47 15 Barry Kelly, Camden and Islington Public Health, London, Uk
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51 16 Mark Hamer, Physical Activity Research Group, Department of Epidemiology and Public
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56 18 *Corresponding author
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60 19 **Key words: physical activity/ active play/ children/ school/ environment**

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For peer review only

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3 38 **INTRODUCTION**
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6 39 Physical activity is essential for every facet of children’s health. However, physical activity
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8 40 levels in British children are low. The school environment is a promising setting to increase
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10 41 children’s physical activity but limited empirical evidence exists on how a change in the
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12 42 outdoor physical school environment influences physical activity behaviour. London
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14 43 Borough of Camden is re-designing seven existing school playgrounds to engage children to
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16 44 become more physically active.
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21 45 The primary aim of this project is to evaluate the impact of the re-designed playgrounds on
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23 46 children’s physical activity, wellbeing, and physical function/fitness.
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29 48 **METHOD AND ANALYSIS**
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32 49 This project will use a longitudinal quasi-experimental design. Seven experimental schools
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34 50 and one control school will take part. One baseline data collection session and two follow-
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36 51 ups will be carried out. Between baseline and follow-up the experimental school
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38 52 playgrounds will be re-designed. At baseline, a series of fitness tests, anthropometric and
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40 53 questionnaire measurements, and 7 day objective physical activity monitoring (Actigraph
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42 54 accelerometer) will be carried out on children (aged 5 to 16 years). This will be repeated at
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44 55 follow-up. Changes in overall physical activity levels and levels during different times of the
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46 56 day (eg, school breaks) will be examined. Multilevel regression modelling will be used to
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48 57 analyse the data.
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60 **ETHICS AND DISSEMINATION**

61 The results of this study will be disseminated through peer-review publications and scientific
62 presentations. Ethical approval was obtained through the University College London
63 Research Ethics Committee (Reference number: 4400/002).

For peer review only

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3 78 **INTRODUCTION**
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6 79 Physical activity is essential for every facet of children's (aged 5 to 16 years) health. For
7
8 80 example, higher levels of physical activity in children are associated with more favourable
9
10 81 cardiovascular disease risk factors whereas excessive levels of sedentary behaviour have the
11
12 82 reverse effect.[1,2] Physical activity can also benefit psychological health by aiding in the
13
14 83 prevention of anxiety and depressive symptoms and contributing to the improvement of
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16 84 self-esteem.[3] Importantly, rather than detracting from learning, more physical activity and
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18 85 breaks from sitting in school are thought to enhance cognitive function and academic
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20 86 performance.[4] It is also more likely that active children will become active adults, since
21
22 87 some tracking of physical activity behaviour has been observed from childhood to
23
24 88 adulthood.[5] However, in westernised countries current levels of physical activity in
25
26 89 children are low as there are increasing opportunities to participate in sedentary
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28 90 activities.[6,7] For example, it is recommended that children engage in physical activity of
29
30 91 moderate intensity for at least one hour a day, to maintain good health.[8] However, just
31
32 92 24% of British girls and 32% of boys achieve this recommendation.[7] Physical inactivity is
33
34 93 estimated to cost the NHS approximately £8 billion per year in health care costs alone.[8]
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36 94 Encouraging physically active lifestyles in children is therefore crucial in nurturing a healthy
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38 95 future generation of adults.
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47 96 A recent meta-analysis found that the effects of interventions to increase physical activity in
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49 97 children have been, at best, modest, and concluded that alternative approaches are
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51 98 required.[9] In the UK, children spend approximately 60% of their weekday in school where
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53 99 physical activity levels, particularly in girls, are low.[10,11] Environments both facilitate and
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55 100 provide the arena for physical activity [12]. Interventions that target the school environment
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3 101 may offer great opportunity to increase physical activity levels. However, there is little
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5 102 robust empirical evidence concerning the effect of changing the physical environment on
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7 103 activity levels in children. Emerging data has suggested that a positive perception of the
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9 104 school play environment was associated with higher levels of moderate-vigorous physical
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11 105 activity (MVPA) during playtime.[13] Moreover, the number of permanent play facilities in
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13 106 school playgrounds has been found to be associated with higher physical activity levels.[14]
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15 107 A recent review [15] on the value of playgrounds for children’s physical activity identified 13
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17 108 experimental studies, which have produced mixed findings, likely owing to differences in
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19 109 intervention design. For example, the review identified that reducing playground density
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21 110 increased physical activity levels, but the provision of play equipment produced mixed
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23 111 effects, whereas no effects were found on the provision of playground markings and
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25 112 promotion of physical activity by teachers. Just one study investigated the impact of “major”
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27 113 playground reconstruction on children’s physical activity behaviour [16] and concluded
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29 114 renovated schoolyards to promote physical activity may increase the number of children
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31 115 who are physically active and may reduce sedentary behaviours. However, physical activity
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33 116 data was collected using direct observation during the school day, only. This limits the ability
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35 117 to examine carry over effects outside the school environment (ie, at weekends and during
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37 118 evenings). Taken together, the emerging evidence suggests that the physical environment
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39 119 could play an important role in children’s physical activity behaviour, but more robust
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41 120 evidence is required.
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122 **Increasing physical activity levels is well established as a way to improve fitness and health**123 **outcomes in young people. Strong’s et al. [1] review identified 17 experimental studies that**

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3 124 aimed to increase levels of physical activity, and these all found improvements in aerobic
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5 125 fitness. Two experimental studies implemented programs of moderately intense exercise 30
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7 126 to 60 minutes in duration, 3 to 7 days per week, and this led to a reduction in total body
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10 127 adiposity in overweight young people. Interestingly, the review also identified three
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12 128 longitudinal and two experimental studies in young people that showed physical activity or
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15 129 strength training improved muscular strength and endurance. It is plausible to assume that
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17 130 an increase in movement and a decrease in sedentary behaviour may result in an increase in
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19 131 hamstring flexibility. This is important as maintaining hamstring flexibility may prevent acute
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22 132 and chronic musculoskeletal injuries.[17] There is also evidence that physical activity is
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24 133 associated with scores on a scale (The Strengths and Difficulties Questionnaire) measuring
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26 134 mental wellbeing (eg, happiness, behaviour, concentration, self-esteem etc).[18] On this
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28 135 basis we hypothesise that a change in the physical school playground environment which
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31 136 increases levels of physical activity or reduces sedentary behaviour should subsequently
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34 137 improve fitness and health outcomes.
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40 139 A recent study found that engaging in 40% of moderate-intensity physical activity during
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42 140 school playtime equated to 34 minutes of daily MVPA.[19] This exceeds the *minimum*
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44 141 recommendation of 30 minutes of at least moderate-intensity physical activity for children's
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47 142 good health.[20] It has been suggested that this guideline is a realistic target for children to
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49 143 achieve during school playtime,[21] especially if a playground has been modified to
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52 144 encourage physical activity.
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3 146 **SETTING**
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6 147 Camden Borough Council is re-designing seven existing school playgrounds (five primary schools and
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8 148 two secondary schools), that are thought not to be conducive to physical activity/ active play, with
9
10 149 exciting bespoke features to engage children to become more active. Each school will receive a
11
12 150 unique playground design, for example displayed in Figure 1. Example features include new
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14 151 Astroturf games pitches, climbing frames, trampolines, monkey bars, and outdoor gyms, which have
15
16 152 been designed based on themes (eg, ancient ruins, volcanoes, clouds etc.) emerging from qualitative
17
18 153 work with children and teachers in each school. The research team did not carry out the qualitative
19
20 154 work nor did they provide input into the design of the playgrounds. The qualitative work and the
21
22 155 design of the playgrounds were carried out by two private organisations specialising in playground
23
24 156 design. Camden Council's underlying goal is to encourage participation by creating
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26 157 opportunities for physical activity outside of traditional sports or team competition. This
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28 158 presents a unique opportunity to evaluate the impact of these structures on children's
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30 159 physical activity, health and wellbeing outcomes while addressing previous limitations in the
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32 160 literature (ie, collecting activity only in school).
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41 162 We hypothesise that the new play grounds will increase young peoples' time spent in both light and
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43 163 moderate-to-vigorous physical activity and reduce sedentary behaviour during break time, and
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45 164 consequently improve levels of general fitness (eg, grip and leg strength, peak flow and adiposity).
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52 166 **AIMS**
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55 167 The *Camden Active Spaces* project consists of two key elements; 1) redesign of the school
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57 168 playgrounds; 2) evaluation of the hypothesised benefits. In the present paper we focus on
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3 169 the evaluation only. Thus, the primary aim of this project is to evaluate the impact of the re-
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5 170 designed playgrounds on children's physical activity, wellbeing, and physical
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8 171 function/fitness.
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14 173 **METHOD AND ANALYSES**

17 174 The evaluation of *Camden Active Spaces* will use a longitudinal quasi-experimental design.
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19 175 Baseline data collection will take place in the Spring/Summer term 2014, follow-up I data
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21 176 collection will take place during the Autumn term 2014, and follow-up II during the Summer
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23 177 term of 2015 (see Figure 2). Between baseline and follow-up I (school summer holidays) the
24
25 178 school playgrounds will be re-designed. A second follow-up will allow us to investigate if
26
27 179 short-term effects of the intervention (if they exist) are sustained over a longer period. This
28
29 180 evaluation has been funded by the Economic and Social Research Council, UK
30
31 181 (ES/M003795/1), whilst the core project (playground redesign) has been funded by Camden
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33 182 Clinical Commissioning Group and London Borough of Camden. Ethical approval was
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35 183 granted by the University College London Research Ethics Committee (4400/002).
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44 185 **Inclusion criteria**

46 186 *School inclusion criteria*

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48 187 Seven schools located in the London Borough of Camden have been selected to receive the
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50 188 re-designed playgrounds and all seven schools have agreed to take part in the study.
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3 190 In addition to the seven experimental schools one control school will be recruited into the study.
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5 191 This school will be located in the London Borough of Camden and it will not be receiving a new
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7 192 playground design, moreover, it will not differ from experimental schools based on student
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9 193 demographics or school policy. Owing to resources it is only feasible to collect data from a single
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11 194 control school. The authors acknowledge that an equal number of controls to experimental schools
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13 195 would allow for a more robust experimental design.

16 17 196 *Participant Inclusion criteria*

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20 197 We aim to randomly select approximately 100 children (see below power calculation) evenly
21
22 198 distributed across school year groups (aged 5 to 11 years in primary school and aged 11 to
23
24 199 16 years in secondary school) from each of the eight schools (total sample size 800).
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27 200 Children aged 17 to 18 years or any school leavers in 2014 will not be asked to participate in
28
29 201 the current project, owing to time table restrictions due to final exams and potential loss to
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31 202 follow up. Students whose parents have not opted them out of the study will be eligible to
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33 203 participate (see section Ethics and Dissemination for details on obtaining consent).
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38 39 40 205 **Recruitment**

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43 206 The seven schools who will be receiving the redesigned playgrounds have previously been
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45 207 recruited into the study by Camden Borough Council. To recruit children into the study
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47 208 presentations will be given to each year group within each school, during assemblies. The
48
49 209 presentations will disseminate information on *Camden Active Spaces*, what would be
50
51 210 involved if children were to take part in the study and benefits of the study to children and
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53 211 the school. At the end of the presentations children will be given participant study
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55 212 information sheets. In order to make parents aware of the study a parent information sheet
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3 213 will be emailed to all parents (translated into different languages where required), posted
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5 214 on the school webpage, in addition to hard copies being made available at the school. In an
6
7 215 attempt to maximise response rates and adherence to protocol, each child who completes
8
9 216 the wear protocol will be awarded a one-month free swimming voucher and entered into a
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11 217 prize draw to win an iPod Touch (one iPod Touch will be awarded per school). All schools
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13 218 taking part in the study will be entered into a separate prize draw to win one of two
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15 219 Nintendo Wiis.
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221 **Procedures**

222 Data collection procedures will take place over a period of 12 months. A team of trained
223 researchers will collect data from each school on a date and time that is convenient for the
224 school. Children will be invited to take part in data collection. Data collection sessions will
225 last approximately 30 minutes. A series of fitness tests and anthropometric measurements
226 will be carried out on children, in an appropriate room in the school (e.g. sports or assembly
227 hall). Once fitness tests and anthropometric measurements have been completed objective
228 devices (accelerometers) will be given to children to monitor their physical activity
229 behaviour. Between four and seven days of accelerometer data are needed to provide a
230 reliable estimate of habitual physical activity.[22] Thus participants will be asked to wear
231 objective devices for 7 consecutive days. On day seven participants will return the device to
232 research staff at the school where they will then complete a questionnaire on their physical
233 activity behaviour. This exact process will be repeated at follow-up I and follow-up II.

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3 235 **Measurement and instruments**
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6 236 *Accelerometer*
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9 237 It is now recognised that accelerometers provide the most reliable and valid measurement
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11 238 of activity in children [16] and are considered the gold standard approach. These wearable
12
13 239 motion sensors measure movement across three dimensions, thus providing minute-by-
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15 240 minute time-stamped data on activity intensity, duration, and patterns across the day.
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19 241 Objective physical activity monitoring has been successfully used in similar study settings to
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21 242 the present project.[14,23, 24]
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24 243 The present evaluation will use the Actigraph GT3X accelerometer. This device is validated
25
26 244 and has been used in other studies with primary and high school children (see for example:
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28 245 www.iconnect.co.uk and <http://www.cedar.iph.cam.ac.uk/research/directory/speedy/>). The
29
30 246 Actigraph GT3X is worn on a belt around the waist with the device itself positioned above
31
32 247 the right hip either over or under clothing. We will employ a sampling frequency of 30 hz.
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34 248 Children will be asked to wear the device during waking hours every day for seven
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36 249 consecutive days, but not during water-based activities or sleep.
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45 251 *Fitness Tests*
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48 252 A series of fitness tests will be carried out, following Standard Operating Procedure Forms,
49
50 253 on all children taking part in the study. Four fitness tests will be carried out to measure
51
52 254 aspects of general fitness: participants will be asked to perform the hand held
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54 255 Dynamometer test to assess grip strength, the standing horizontal jump test to assess leg
55
56 256 power, the peak flow test to assess lung function, and the sit-and-reach test to assess
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3 257 flexibility. Participants' weight and body composition will be measured using the Tanita SC-
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5 258 330 Body Composition Analyser (Tanita Inc, IL, USA) and height will be measured using the
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8 259 Leicester Height Measure, from which BMI will be calculated kg/m^2 . These tests have been
9
10 260 extensively used in previous cohort studies of young people (eg,
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12 261 <http://www.chasestudy.ac.uk/study-measurement>) and have shown good validity and
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14 262 reliability in young people across broad age groups (<http://www.chasestudy.ac.uk/study->
15
16 263 [measurement](http://www.chasestudy.ac.uk/study-measurement)). [25-27]

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21 22 23 265 *Questionnaires*

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26 266 All children taking part in the study will be asked to complete a questionnaire. The
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28 267 questionnaire will take approximately ten minutes to complete and includes questions on
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30 268 standard demographics and physical activity, as well as potentially important correlates of
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32 269 physical activity. Teaching assistants and research staff will assist all children in completing
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34 270 questionnaires.

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39 271 The Girls Health Enrichment Multi-Studies (GEMS) physical activity survey has been
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41 272 embedded within the questionnaire to give a subjective measure of physical activity and
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43 273 provide an understanding of which specific physical activity behaviours are influenced by
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45 274 the playground redesign, if any. GEMS has validity and reliability equivalent to other self-
46
47 275 report measures of physical activity [28] and was deemed suitable for both primary and high
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49 276 school boys and girls by those who designed the present study, owing to its simplicity. The
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51 277 questionnaire also includes items on travel mode (as used in the iConnect Study;
52
53 278 www.icconnect.co.uk).

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3 279 Teachers will be asked to complete the validated Strengths and Difficulties
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5 280 questionnaire;^[29] this questionnaire provides a measure of children's behaviour, mental
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7 281 health, engagement and well-being and takes approximately five minutes to complete per
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10 282 child.
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13 283 Each school has one Head Teacher. Head Teachers (n=8) will be asked to complete a
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15 284 questionnaire to allow for an understanding of differences between schools on "playground
16
17 285 policy." Questions include, "During what type of weather are children not allowed to go
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19 286 outside during scheduled breaks (i.e. rain/ snow)?" "Are any sections of the current
20
21 287 playground out of use during bad weather (i.e. school field when raining), if yes please
22
23 288 specify?" "When children cannot go outside on scheduled breaks, owing to bad weather,
24
25 289 where do they spend their break?" and "Are there any current initiatives/programs to
26
27 290 promote physical activity and/or healthy lifestyles in your school, if yes please specify?"
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30 291 Head teachers will be asked to complete an identical survey at follow-up to allow for the
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32 292 assessment of changes in "playground policy" between each time point.
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294 **ANALYSIS**

295 *Outcome*

296 The primary outcome for this study will be change in average daily time spent in MVPA as
297 recorded by the Actigraph accelerometer. In addition the study has been designed to collect
298 the following secondary outcomes using participant questionnaires and objective measures
299 (1) change in average daily time spent sedentary, (2) change in average daily time spent in
300 light and vigorous activity at different times of the day (playtimes at school, leisure time at

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3 301 home), (3) change in peak flow, sit-and-reach, grip strength, standing horizontal jump, and
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5 302 body mass index (BMI)/body composition, (4) change in Strength and Difficulties scores.
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11 304 *Quantitative analysis*
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15 305 Raw data files will be extracted from each Actigraph device and processed using bespoke
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17 306 software (Actilife) to quantify a range of features that will directly contribute to the
18
19 307 determination of active and sedentary time. We intend to follow methods used in the
20
21 308 International Children's Accelerometry Database study that incorporated children aged 4-18
22
23 309 yrs old [2]. Briefly, data files will be reintegrated to a 60-second epoch and non-wear time
24
25 310 defined as 60 minutes of consecutive zeros, allowing for 2 minutes of non-zero
26
27 311 interruptions. All children with at least 1 day with at least 500 minutes of measured monitor
28
29 312 wear time between 7 AM and midnight will be included. Total physical activity will be
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31 313 expressed as total counts, including sedentary minutes, divided by measured time per day
32
33 314 (counts/min, cpm). Time spent sedentary will be defined as all minutes showing less than
34
35 315 100 cpm and MVPA time as minutes showing more than 3000 cpm. Multilevel modelling will
36
37 316 be used to analyse the data. This approach offers several advantages over simple regression
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39 317 models. We will be able to model changes in activity over the three assessment periods
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41 318 accounting for the inter-individual as well as intra-individual differences.
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52 320 *Sample size*
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55 321 A previous school based intervention to examine the effects of changes in playground
56
57 322 structure on physical activity [23] demonstrated a small effect size ($d = 0.10$). Thus, based on
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3 323 these data, a sample size of N=458 would provide us with 80% power at 5% significance
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5 324 level to detect small differences in moderate intensity physical activity using a repeated
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7 325 measures design (calculated using G-Power). We will aim to recruit 100 children from each
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10 326 school to allow for dropout and incomplete Actigraph data.
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17 328 **LIMITATIONS**

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21 330 It is not possible to carry out a multicentre cluster randomised-controlled-trial. Key limitations of this
22
23 331 study include a quasi-experimental design with non-randomly selected control participants and the
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25 332 recruitment of one control school.
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32 334 **ETHICAL CONSIDERATION AND DISSEMINATION**

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35 335 Firstly, head teachers from each school will be asked to provide explicit written consent for
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37 336 their schools and school children to take part in the study. Next, if parents (of primary and
38
39 337 secondary school children) do not want their child(ren) to take part in the study they will be
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41
42 338 given the option to “opt-out” their child(ren), instructions to parents on how to opt-out
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44 339 their child(ren) are provided in the parent study information sheet. Prior to data collection
45
46 340 all high school (not primary school) children will be asked to provide explicit written assent.
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50 341 The findings from this study will be disseminated to academic researchers and to
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52 342 policymakers through several mechanisms. First, we will employ the usual avenues for
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54 343 dissemination of academic research, including conference presentations and journal
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56 344 articles. Second, we will disseminate this research via social media outlets such as the
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3 345 University College London – Physical Activity Research Group Twitter account. Third, with
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5 346 Camden Council, we will include this physical activity study within the regular programme of
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7 347 briefings that are presented to government departments interested in physical activity,
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9 348 including the Department of Health, the Department for Communities and Local
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11 349 Government, etc.
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20 351 **Competing interests**

21
22 352 The authors declare that they have no competing interests.
23
24

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26
27
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29
30

31 355 **Authors' contributions**

32
33
34 356 Lee Smith, Courtney Kipps, Daniel Aggio, Paul Fox, Nigel Robinson, Verena Trend, Suzie
35
36 357 Munnery, Barry Kelly, and Mark Hamer made substantial contribution to the concept and
37
38 358 design of the study. Lee Smith drafted the manuscript and Courtney Kipps, Daniel Aggio,
39
40 359 Paul Fox, Nigel Robinson, Verena Trend, Suzie Munnery, Barry Kelly, and Mark Hamer
41
42 360 revised it critically for important intellectual content. Lee Smith, Courtney Kipps, Daniel
43
44 361 Aggio, Paul Fox, Nigel Robinson, Verena Trend, Suzie Munnery, Barry Kelly, and Mark Hamer
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46 362 approved the final version of the manuscript to be published.
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365 **Figure Legends**

366 **Figure 1: Example of new playground designs**

367 **Figure 2: Overview of study design**

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For peer review only

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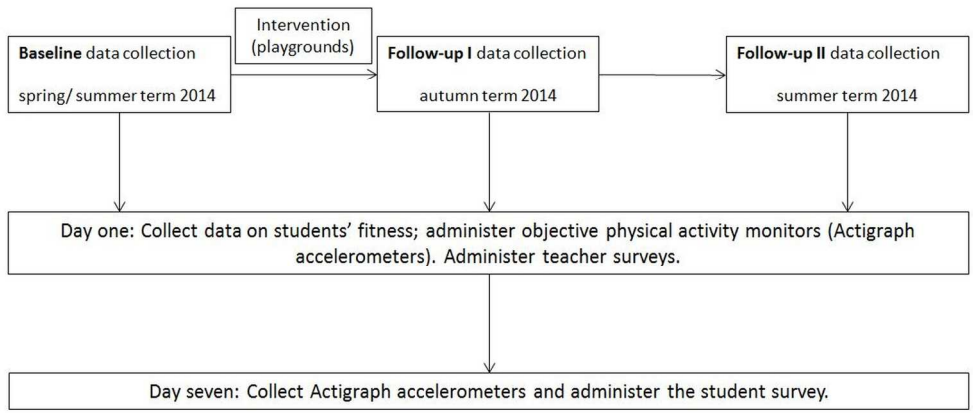
Figure 1: Example of new playground designs



90x49mm (300 x 300 DPI)

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract YES
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found YES
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported YES
Objectives	3	State specific objectives, including any prespecified hypotheses YES
Methods		
Study design	4	Present key elements of study design early in the paper YES
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection YES
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up YES
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants YES
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable YES
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group YES
Bias	9	Describe any efforts to address potential sources of bias YES
Study size	10	Explain how the study size was arrived at YES
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why YES

Statistical methods

12 (a) Describe all statistical methods, including those used to control for confounding

YES

(b) Describe any methods used to examine subgroups and interactions

NA

(c) Explain how missing data were addressed

NA

(d) *Cohort study*—If applicable, explain how loss to follow-up was addressed*Case-control study*—If applicable, explain how matching of cases and controls was addressed*Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy

NA

(e) Describe any sensitivity analyses

Continued on next page

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Results

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	NA
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	NA
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	YES
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	NA
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	NA
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	NA
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	NA
		(b) Report category boundaries when continuous variables were categorized	NA
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	NA
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	YES
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	NA
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA

Other information

Funding 22 Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

YES

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.