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1 Exploring changes in physical activity, sedentary behaviours and hypothesized mediators in the NEAT
2 girls group randomized controlled trial

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1 **Abstract**

2 **Objective.** To evaluate the impact of a 12-month school-based multi-component program on
3 adolescent girls' physical activity and sedentary behaviours, and hypothesized mediators of physical
4 activity behaviour change.

5 **Design:** Group randomized control trial with 12-month follow-up.

6 **Methods.** The intervention, guided by Social Cognitive Theory, involved 357 adolescent girls (13.2 ±
7 0.5y) from 12 secondary schools (6 intervention schools, 6 control schools) in low-income
8 communities in the Hunter and Central Coast regions of New South Wales, Australia.

9 The targeted intervention included enhanced school sport, lunchtime physical activity sessions,
10 interactive seminars, student handbooks, nutrition workshops, pedometers, parent newsletters and text
11 messages to encourage physical activity and healthy eating. Outcomes were assessed at baseline and
12 12-months and included: physical activity (accelerometers), sedentary behaviours (questionnaire and
13 accelerometers), and social-cognitive mediators of physical activity (questionnaire).

14 **Results.**

15 There were significant between group differences in favour of the intervention group for self-
16 reported recreational computer use (-26.0 minutes; 95% CI, -46.9 to -5.1), and sedentary
17 activities summed (-16 56.4 minutes; 95% CI, -110.1 to -2.7), however objective sedentary
18 behaviour showed no differences. There were no group-by-time effects for any of the physical
19 activity outcomes or hypothesized mediators.

20 **Conclusion.** A school-based intervention designed for adolescent girls from schools located in low-
21 income communities significantly reduced time spent in sedentary activities. However, improvements
22 in physical activity and hypothesized mediators of physical activity behaviour were not observed.
23 Future studies are encouraged to explore alternative mechanisms of behaviour change derived from
24 integrated and socio-ecological theories.

25 **Trial Registration:** Australian New Zealand Clinical Trials Registry No:

26 ACTRN12610000330044

27 **Key words:** Adolescent girls, intervention, obesity prevention, health behaviours

28

1 **Introduction**

2 Considering the consequences of obesity¹ and the high likelihood of obesity persisting into
3 adulthood², obesity prevention is a global health priority. However, evidence for effective obesity
4 prevention and treatment interventions targeting youth have been limited by a lack of high quality of
5 studies. Methodological weaknesses of previous studies include the lack of a theoretical framework to
6 guide behaviour change, self-reported outcome measures, inadequate intervention duration and/or
7 intensity, poor program compliance and short-term follow-up³. Furthermore, few obesity prevention
8 interventions have examined hypothesized mediators of intervention effects on targeted behaviours
9 such as physical activity⁴. This process is important for establishing the causal mechanisms of
10 behaviour change, which can inform the design and delivery of more effective programs in the future.
11 Clearly, the evaluation of more rigorously designed studies for adolescents is needed.

12 Evidence suggests that multi-component, school-based interventions that target behaviour
13 change at multiple levels can prevent short-term unhealthy weight gain⁵. Moreover, it has been
14 indicated that these interventions may be more efficacious if targeted towards certain groups and
15 differentiated on the basis of sex, age and socio-economic status (SES)⁶. Despite higher levels of
16 obesity and overweight typically observed in areas of social and economic disadvantage⁷, few school-
17 based interventions have targeted youth living in low-income communities. The transition from
18 childhood to adolescence is characterized by a marked deterioration in physical activity and dietary
19 behaviours^{8,9}. Moreover, higher levels of sedentary behaviour and poorer dietary and physical activity
20 behaviours are often reported for those living in low-income communities, especially among girls^{10,11},
21 placing this group at an even greater risk of obesity.

22 The current study aims to address the limitations of previous obesity-related prevention
23 interventions that have targeted adolescents. The Nutrition and Enjoyable Activity for Teen Girls
24 (NEAT Girls) program was a 12-month school-based group randomized control trial designed to
25 prevent unhealthy weight gain in adolescent girls living in low-income communities through
26 improving physical activity, dietary and sedentary behaviours. The impact of the NEAT Girls
27 intervention on body composition has been reported elsewhere¹². This paper provides a comprehensive
28 report of the 12-month intervention effects for i) time spent in moderate (MPA), vigorous (VPA) and

1 moderate-to-vigorous physical activity (MVPA) within and beyond the school day, and ii) time spent
2 in total and selected screen-based and non screen-based sedentary behaviours, and iii) hypothesized
3 mediators of physical activity behaviour change.

4 **Methods**

5 Detail of the NEAT Girls study design, methods and participant characteristics at baseline have been
6 described previously¹³. Briefly, the intervention is a 12-month school-based clustered randomized
7 control trial with a 12- and 24- month follow-up. The program was developed for adolescent girls
8 attending public secondary schools located in ‘low-income’ communities as determined by the Socio-
9 Economic Indexes for Areas of relative socioeconomic disadvantage (SEIFA Index)¹⁴. Schools were
10 eligible to participate if located in areas that had an allocated SEIFA index of ≤ 5 (bottom 50%). 18
11 schools were randomly selected from a list of eligible schools in the Hunter, Newcastle and Central
12 Coast areas in New South Wales, Australia. If the first school on the list were to decline, the next
13 school was invited and this iterative process continued until 12 schools had been recruited. Study
14 participants were in Grade 8 at the time of recruitment. Ethics approval was obtained from the relevant
15 institutional boards. Written consent was obtained from the School Principal of recruited schools, study
16 participants and their parents. A sample size calculation is described elsewhere¹³, but was based on
17 change in body mass index (BMI) being the primary outcome for the NEAT girls
18 intervention.

19 Baseline and 12-month (program conclusion) assessments were collected during May and June
20 in 2011 and 2012. Following baseline assessments, schools were match-paired based on their size,
21 geographic location and demographics. Schools within each pair were then randomized by an
22 individual not involved in the project to either the NEAT Girls intervention or a wait list control group.

23 Bandura’s SCT¹⁵ provided the theoretical framework for the program. Specifically, the
24 program targeted the following psychological, behavioural and environmental influences on physical
25 activity: self-efficacy, social support, behavioural strategies, perceived physical environment, outcome
26 expectations (perceived benefits) and expectancies (value placed on perceived benefits). The current
27 study comprised a multi-component program where delivery was shared between Physical Education

1 teachers from the study schools and members of the research team. Specifically, teachers delivered the
2 enhanced school sport sessions and lunchtime physical activity sessions, while accredited dieticians
3 delivered the nutrition workshops. The enhanced school sport sessions and nutrition workshops were
4 implemented during existing timetabled school sport, while the lunchtime physical activity sessions
5 supplemented the enhanced school sport sessions. Members of the research team delivered the
6 interactive educational seminars and distributed text messages to reinforce and encourage targeted
7 health behaviours. Additional program components involved the use of pedometers, student handbooks
8 and parent newsletters. All intervention materials were developed by the research team. Teachers from
9 the study schools involved in the intervention attended a full day training workshop designed to
10 support the implementation of the program in their school. An outline of the intervention strategies,
11 hypothesized SCT mediators of physical activity behaviour change and their respective measures is
12 provided in Table 1.

13 ***Outcome measures.*** Participants wore Actigraph accelerometers [MTI models 7164, GT1M
14 and GT3X (ActiGraph, LLC, Fort Walton Beach, FL)] positioned on their hip for seven
15 consecutive days during waking hours, except during aquatic activities. Accelerometers were
16 distributed to participants for immediate wearing on the same day that all other assessments were
17 conducted. Comparisons of the output generated by the various Actigraph accelerometers
18 suggests that the data are comparable for estimating physical activity¹⁶. Uniaxial data were
19 collected in 30-second epochs and activity thresholds¹⁷ were used to calculate time spent sedentary
20 (≤ 50 counts) and in moderate (1148 – 2005 counts) and vigorous (≥ 2006 counts) activity. Strings of
21 consecutive 0 counts ≥ 20 minutes were defined as non-wear time and were subsequently removed
22 during data reduction. Data were included in the analyses if a participant wore the monitor for at least
23 600 minutes per day for at least three days, including a weekend day. Data were reduced to obtain
24 physical activity outcomes for the following given periods: total wear-time, weekdays, school hours
25 and after school hours. After school hours was determined as the period of time from when school
26 ended for each participant (which ranged from 2.05pm and 3.20pm) to 6.00pm for all participants. To

1 account for differences in wear-time and school start and finish times, the outcomes used on the
2 analyses were mean counts per minute (CPM) and percentage of time in MPA, VPA and MVPA.

3 Sedentary behaviour were assessed using accelerometers and the Adolescent Sedentary
4 Activity Questionnaire (ASAQ)^{18,19} which provided self-reported time spent in a variety of sedentary
5 activities over the last seven days. These included: watching television and DVDs, recreational
6 computer use, inactive travel (i.e., by car/bus/train) and inactive socializing (i.e., sitting while talking
7 on the phone or with friends). A composite variable summing all sedentary activities was also
8 calculated. A daily average for each sedentary activity variable was then determined.

9 Six social cognitive scales for physical activity were used and included: self-efficacy,
10 perceived environment, social support, behavioural strategies, outcome expectations and outcome
11 expectancies related to physical activity. Specifically, the referent for each scale was regular MVPA
12 (defined as “*participating in a total of 60 minutes of at least moderate intensity activity on all or most*
13 *days of the week*”). The scales were previously tested in an adolescent sample (n = 171, mean age 13.6
14 ± 1.2 years)²⁰. A description of each scale and its psychometric properties are reported in Table 1.

15 Chi squares and independent sample *t* tests [PASW Statistics 17 (SPSS Inc)] were used to
16 explore baseline group differences for each of the variables ($p < 0.05$). The analysis followed the
17 intention to treat principle and was conducted using established linear mixed models, which were
18 adjusted for the clustered nature of the data (i.e., school level was included in the models)²¹.

19 Accelerometer derived outcomes were also adjusted for the different accelerometer models used. SAS
20 version 9.1 (SAS Institute Inc.) was used to analyze the mixed models using the PROC MIXED
21 statement. To test for mediation of hypothesized social-cognitive variables on physical activity
22 behaviour, a mediation analysis would involve the following: i) an action theory test (i.e. to determine
23 impact of intervention on hypothesized mediators), ii) a conceptual theory test (i.e. to examine an
24 association between changes in potential mediators and dependent variable) and iii) a significance test
25 of the mediated effect.

26 **Results**

1 The study sample is described in more detail elsewhere¹³ which included 357 adolescent girls
2 [13.2 (0.5) years]. At baseline, the percentage of participants classified as overweight or obese were
3 26.1% and 16.8% respectively. A total of 246 girls met the physical activity inclusion criteria based on
4 accelerometer wear-time at baseline and/or 12 months (≥ 600 minutes per day for at least 3 days
5 including a weekend day). This translates to 61.9% ($n=221$) of the total sample at baseline and 24.6%
6 ($n = 88$) at 12 months. There were no significant group-by-time effects for any of the physical activity
7 outcomes (Table 2). Self-report data showed girls in the intervention group had a significantly greater
8 reduction in recreational computer use (-26.0 min/day; 95% CI, -46.9 to -5.1; $p = 0.02$) and sedentary
9 activities summed (-56.4 min/day; 95% CI -110.1 to -2.7; $p = 0.04$) than their control peers. The
10 change in time for inactive travel was marginally in favor of the intervention group with a between
11 group difference of -8.6 min/day (95% CI, -18.1 to 1.0, $p = 0.07$). However, results for objectively
12 measured sedentary behaviour showed both groups remained relatively stable with time producing no
13 between group differences.

14 Although changes were in favor of the intervention group for most of the social-cognitive
15 variables (exception for perceived environment at school and family support), there were no
16 statistically significant group-by-time effects for any of the outcomes. Further, as the intervention
17 effect on hypothesized mediators (i.e., action theory test) was not statistically significant we did not
18 conduct conceptual theory tests or test the significance of the mediated effect.

19 **Discussion**

20 To our knowledge, this is the first RCT to evaluate a school-based obesity prevention program
21 targeting adolescent girls living in low-income communities in Australia. The intervention significantly
22 reduced girls' time spent in self-reported sedentary activities. Specifically, girls in the intervention
23 group reported less time in computer use for recreation (-26 minutes/day) and sedentary activities
24 summed (-56 minutes/day) compared to girls in the control group. Meanwhile no difference in
25 objectively measured sedentary behaviour was observed. However, these findings could be due to
26 social-desirability bias that self-report measures are susceptible to, and the clear differences in the
27 types of sedentary behaviour that both measures capture. While the self-report measure specifically

1 examined time spent in small-screen recreation, inactive travel and inactive socializing, the
2 accelerometer data captured total sedentary minutes, which potentially encompasses a vast array of
3 sedentary activities by the participants that substantially extend beyond the activities that were self-
4 reported.

5 Despite careful design and implementation, the intervention did not impact upon any of the
6 physical activity outcomes or the hypothesized mediators of physical activity behaviour change. These
7 results support findings from a recent review of behavioural interventions to prevent obesity in youth,
8 which indicated that strategies to reduce unhealthy behaviours (e.g. decreasing sedentary behaviours)
9 seem to be more effective than strategies to increase healthy behaviours, such as physical activity²².
10 These changes have important implications, as emerging evidence suggests that the adverse health
11 outcomes associated with sedentary activities (e.g., overweight and obesity, metabolic syndrome) are
12 independent of physical activity²³. While the current study placed more emphasis on reducing time
13 spent in screen-based recreation than other sedentary behaviours, significant and marginally significant
14 intervention effects were still observed for self-reported sedentary activities summed ($p = 0.04$) and
15 inactive travel ($p = 0.07$) respectively.

16 No significant results were found for within or beyond school day physical activity. Besides a
17 lack of an intervention effect, problematic measurement may help to explain these null findings.
18 Accelerometers lack the sensitivity to detect non-ambulatory movements. Hence these devices do not
19 capture all types of physical activity, and this is a potential limitation for the current study considering
20 the NEAT Girls intervention promoted a range of physical activities, some of which are non-
21 ambulatory in nature (e.g. resistance training). Additionally, poor accelerometer compliance (61.9%
22 and 24.6% at baseline and post-test respectively) has resulted in a small and potentially underpowered
23 number of cases that were eligible to be included in the analyses. Anecdotally participants expressed
24 physical discomfort while wearing the devices. Further it is possible that social stigma and personal
25 embarrassment associated with wearing the devices may explain poor compliance. The impact of poor
26 participant compliance on the attrition of valid (i.e. insufficient wear-time to meet inclusion criteria)
27 accelerometer data has been noted by other studies^{24,25}. Further investigation of strategies to improve
28 accelerometer compliance in adolescents is clearly warranted.

1 It is also possible that intervention dose was compromised by poor participation rates and
2 fidelity of intervention implementation. For example, we previously reported that intervention
3 delivery fidelity was found to be 74.0%. Intervention girls attended on average less than half of the
4 total physical activity sessions (42.5%), and attempted only 9.0% of home physical activity and
5 nutrition challenges¹². Although data shows the parent newsletters (74.5%) and text messages (91.0%)
6 were accessed by most in the intervention group, it is unknown if these were read by participants and
7 parents. While reasons for poor participation rates or affected intervention delivery were not
8 documented, this is perhaps important information for future studies to attain. Qualitative research of
9 this kind may assist identification of effective strategies to improve intervention fidelity.

10 Meanwhile other interventions targeting adolescent girls have experienced similar challenges
11 in their attempts to improve physical activity behaviours. For example, the Stanford GEMS studies
12 evaluated community- and home-based obesity prevention programs in pre-adolescent girls living in
13 low-income communities²⁶. Despite their high quality design and implementation, neither study
14 impacted positively on physical activity. Similarly, the school-based New Moves intervention²⁷ failed
15 to increase adolescent girls' self-reported physical activity, although physical activity stage of change
16 did increase. Like the New Moves study, many previous interventions targeting adolescents' physical
17 activity have relied on self-reported measures, which may be prone to respondent bias. A notable
18 exception was the Trial of Activity for Adolescent Girls (TAAG). While this study adopted a socio-
19 ecological framework to reduce the decline in physical activity, intervention effects were only modest
20 (a between group difference of 1.6 minutes of daily MVPA per day)²⁵. Together, these studies highlight
21 the challenges of working with adolescent girls to reduce the decline in physical activity typically
22 observed in this cohort.

23 Few studies have examined potential mediators of physical activity in youth interventions⁴. A
24 successful school-based intervention in adolescent girls found self-efficacy, perceived benefits and
25 barriers, and commitment to planning to mediate changes in physical activity behaviour²⁸.
26 Alternatively, there was no support for the mediating influence of self-efficacy, perceived barriers or
27 enjoyment in the school-based Project-FAB intervention²⁹, which also targeted adolescent girls.

1 Although the NEAT Girls intervention components promoting physical activity were carefully
2 developed to target evidence-based social-cognitive and behavioural determinants of activity^{4, 30}, there
3 were no significant treatment effects for any of these outcomes. Our null findings may suggest that the
4 intervention strategies and/or dose received were not sufficient to produce changes in the hypothesized
5 mediators. In addition, these findings may in part, be explained by the 12-month study period, which is
6 longer than the majority of earlier adolescent interventions which have involved relatively short study
7 periods (e.g., ≤ 6 months)³. Meanwhile there is potential for the current mediator measures used to lack
8 specificity and hence sensitivity to detect change. For example, the physical activity self-efficacy
9 measure scales provided a global measure of self-efficacy, and a more specific measure(s) of efficacy
10 related to physical activity (e.g. task, barriers, asking or environmental-change efficacy) may have been
11 more beneficial. Finally, it is plausible that the targeted social cognitive constructs may not be effective
12 mediators of behaviour in this specific group. Previous studies examining the mechanisms of physical
13 activity behaviour change in youth interventions have focused almost exclusively on constructs from
14 SCT, the Transtheoretical Model and the Theory of Planned Behaviour⁴. These theories were
15 developed to explain adult behaviours and emphasize the individual level (e.g., self-efficacy, intention)
16 determinants of behaviour. While consistent evidence for the most effective mediators of behaviour
17 have not emerged from these models, future studies may be encouraged to examine alternative
18 mechanisms derived from integrated and socio-ecological models. Social ecological models of health
19 behaviour provide guiding frameworks for intervention strategies that target changes beyond the
20 individual level by addressing potential environmental and policy influences. Clearly, continued efforts
21 are needed for theoretically guided interventions that will help develop a stronger evidence-base for
22 mediators of behaviour change in adolescent populations.

23 There are several strengths of the NEAT Girls study that should be noted. These include the
24 use of a group randomized controlled trial, our monitoring of intervention fidelity, the 12-month study
25 period, the at-risk study sample, high retention rate at post-test (83%) and use of an objective measure
26 of physical activity. However, the limitations should also be noted. There were a large percentage of
27 participants not attending weekly program sessions or completing weekly challenges which may have
28 reduced the intensity of the intervention as originally intended. Significant effects reported here for

1 sedentary behaviours were from a self-report measure, suggesting the possibility of response bias due
2 to post-intervention social-desirability. The absence of any statistically significant findings for
3 sedentary behaviour or physical activity measured by accelerometry may have been impacted by poor
4 participant compliance resulting in a sample size that was underpowered for these analyses. While
5 assessors were blinded at baseline, this was not the case when 12-month assessments were conducted.
6 Finally, due to concerns for participant burden, theoretical measures of sedentary behaviour were not
7 included during assessments.

8

9 **Conclusion**

10 A school-based intervention designed for adolescent girls from schools located in low-income
11 communities significantly reduced time spent in self-reported (but not objectively measured) sedentary
12 activities . However, improvements in physical activity and hypothesized mediators of physical activity
13 behaviour were not observed. Future studies are encouraged to explore alternative mechanisms of
14 behaviour change derived from integrated and socio-ecological theories.

15

16 **Practical implications**

- 17 • Interventions targeting adolescent girls may require additional environmental changes to
18 support health behaviour change.
- 19 • Behavioural interventions such as the NEAT Girls program may be more effective in reducing
20 sedentary behaviour than increasing physical activity.
- 21 • Future interventions are encouraged to examine more specific hypothesized mediators of
22 physical activity and sedentary behaviour.
- 23 • Strategies to improve intervention fidelity, such as comprehensive professional development
24 for teachers may improve the effects of school-based interventions.

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