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Intervention to Reduce Recreational Screen-Time in Adolescents: Outcomes and Mediators from the 'Switch-Off 4 Healthy Minds' (S4HM) Cluster Randomized Controlled Trial

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ABSTRACT

Introduction: The primary objective was to evaluate the impact of the 'Switch-off 4 Healthy Minds' (S4HM) intervention on recreational screen-time in adolescents.

Methods: Cluster randomized controlled trial with study measures at baseline and 6-months (post-intervention). Eligible participants reported exceeding recreational screen-time recommendations (i.e., > 2 hours/day). In total, 322 adolescents (mean age = 14.4 ± 0.6 years) from eight secondary schools in New South Wales, Australia were recruited. The S4HM intervention was guided by Self-Determination Theory and included: an interactive seminar, eHealth messaging, a behavioral contract and parental newsletters. The primary outcome was recreational screen-time. Secondary outcomes included mental health (i.e., well-being, psychological distress, self-perceptions), objectively measured physical activity, and body mass index (BMI). Outcome analyses were conducted using linear mixed models and mediation was examined using a product-of-coefficients test.

Results: At post-intervention, significant reductions in screen-time were observed in both groups, with a greater reduction observed in the intervention group (-50 min/day versus -29 minutes, p <.05 for both). However, the adjusted difference in change between groups was not statistically significant (mean = -21.3 min/day, p = 0.255). There were no significant intervention effects for mental health outcomes, physical activity or BMI. Significant mediation effects for autonomous motivation were found.

Conclusions: Participants in both the S4HM intervention and control groups significantly reduced their screen-time, with no group-by-time effects. Enhancing autonomous motivation might be a useful intervention target for trials aimed at reducing adolescents' recreational screen-time.

Trial Registration: ACTRN12614000163606

Keywords: Screen, sedentary behavior, school, physical activity.

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Introduction

Excessive recreational screen-time is associated with numerous adverse physical [1, 2] and mental health [3, 4] outcomes in youth. Despite international guidelines recommending young people limit their recreational screen-time to less than two hours per day [5], between 70-80% of Western youth exceed these recommendations [6-8]. As excessive screen-time is a major public health issue in many Western countries, there is a need for scalable interventions that can reach a large proportion of the youth population. According to a recent meta-analysis of screen-time interventions, home-based interventions have been more successful than those conducted in schools [9]. However, few of the included studies targeted adolescents, and it is therefore unclear which intervention approaches are most effective for this priority population. While parental involvement is considered an important determinant of success in youth screen-time interventions [9], engaging parents in such interventions remains challenging [10]. Schools have the facilities and personnel to support the implementation of interventions [11], but may also have value as an avenue for accessing and engaging parents. Indeed, embedding health promotion interventions within schools may give health promotion programs the exposure and credibility needed to convince parents to participate. Moreover, there is a rationale for evaluating interventions that meaningfully incorporate parental engagement within school-based programs.

Evidence suggests theory-based screen-time interventions have been more effective than those that do not report a theoretical framework [12]. Therefore, an additional priority for interventions should be the application of behavioral theories, and the evaluation of theoretical mediators of behavior change. Self-determination theory (SDT) is a motivational theory which posits that human motivation and behavior are influenced by the satisfaction (or thwarting) of individuals' basic psychological needs for autonomy (sense of choice or volition), competence (sense of capability or mastery) and relatedness (sense of connectedness with others) [13]. According to SDT, satisfaction of these psychological needs will promote autonomous (or self-determined) forms of motivation. Autonomous motivation reflects more 'internalized' reasons for engaging in (or avoiding) a behavior. For example, an individual may decide to maintain an active lifestyle or limit their alcohol consumption due to the perceived health or social benefits. Autonomous motives are considered to be more strongly related to behavioral enactment than controlled motives, which involve engaging in or changing behavior on the basis of external demands or social pressures [13]. Accordingly, behavior change strategies that enable individuals to feel their decisions are self-endorsed

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(rather than imposed) should result in a greater likelihood of initial behavior change and ongoing behavior maintenance [14].

The aim of the present study is to evaluate the efficacy of the 'Switch-off 4 Healthy Minds' (S4HM) intervention, a novel and theoretically based screen-time intervention for adolescents. We hypothesize that adolescents in the S4HM intervention will report significantly lower levels of recreational screen-time at 6-month post-intervention, compared to those in a wait-list control group. In addition, we hypothesize that changes in screen-time over the study period will be mediated by changes in adolescents' autonomous motivation to limit their screen-time.

Methods

Study design and participants

The study was conducted and reported in accordance with the Consolidated Standards of Reporting Trials (CONSORT) Statement [15, 16], and the methods have previously been described in detail [17]. Ethics approval for the study was obtained from the University of Newcastle, Newcastle-Maitland Catholic Schools Office and the Diocese of Broken Bay. All Catholic secondary schools (N = 20) located in the Hunter region of New South Wales, Australia were invited to participate, and the first eight schools to provide written consent were accepted (Figure 1). Students in Grade 7 at the study schools completed an eligibility questionnaire, which asked them to report their total time spent using screen devices for the purposes of recreation on a typical school day. Students failing to meet national screen-time guidelines (i.e., > 2hours/day) were considered eligible and invited to participate, and the first 40 students from each school to return signed consent letters were included. The intervention was evaluated using a parallel group cluster randomized controlled trial (RCT) design. Prior to baseline assessments, schools were matched on key demographic variables (e.g., size, location and socio-economic status) and randomly allocated to the S4HM intervention group or a wait-list control group. The S4HM group received the intervention over a 6- month period, whereas the control group were asked to continue with their usual behaviors and school curriculum. At the end of the study period the control group was offered the S4HM program. Baseline assessments were conducted at the study schools by trained research assistants between April and June, 2014 and follow-up assessments were conducted between October and December, 2014. Basic demographic information (i.e., sex, country of birth, language spoken at home) and self-report measures were collected in exam-like conditions

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using an online survey and Apple iPads, and physical measures were conducted discretely by a same-sex assessor.

Intervention components

The S4HM intervention components were guided by SDT, targeted both students and their parents, and were designed to be scalable. A detailed description of each intervention component can be seen in Table 1. At the beginning of the study period, students participated in an interactive seminar delivered at the school by a member of the research team. The purpose of the interactive seminar was to provide students with a rationale for behavior change, by outlining the potential consequences of excessive screen viewing, as well as the health and social benefits that could be gained by limiting recreational screen viewing to healthy levels. During this interactive seminar, students were also taught how to self-monitor their screen-time and were given instructions on appropriate screen-time goal setting.

The primary intervention component in the present trial was eHealth messaging. Intervention participants received informational and motivational messages twice per week from their preferred social media and messaging systems (i.e., Twitter, Facebook, Kik, email or text messages). The messages were framed to satisfy students' basic psychological needs for autonomy (e.g., *"Many Australian adolescents spend more time on screens on the weekend. Why not plan your weekends in advance?")*, relatedness (e.g., "*Have a competition with ur m8. Who can go the longest without checking their social media account (Facebook/twitter etc.*)"), or competence (e.g., *"If you're watching TV or using the computer, don't forget to walk around and stretch. It's easy and good 4 u, u can do it!*").

In addition to the student-level strategies, S4HM also targeted the home environment by sending information to parents. Over the study period, parents were mailed a total of six newsletters (i.e., one per month) that included information on the consequences of excessive screen-time and practical strategies for setting limits on screen viewing in the family home. The third newsletter included a behavioral contract, and parents were encouraged to involve their child in the creation of a customized contract, that included clear screen-time goals, as well as rewards/consequences for satisfying or not satisfying the terms of the contract. Newsletters for parents encouraged the planning of individual consequences if screen-time remained excessive, for example "*loss of privileges to TV, iPad, phone etc. for a period of time*". Notably, the strategies provided to parents in the newsletters encouraged parents to interact with their teen in a 'needs supportive' manner and to manage conflict arising from

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attempts to reduce recreational screen-time, e.g. "*Explain to your teen why it is important to limit their screen-time*". Parents are 'needs supportive' when they support their children's sense of autonomy, interact with their children in a warm and responsive manner, and support and encourage self-expression [18].

Primary outcome

A detailed description of the study measures is available elsewhere [17]. Recreational screen-time was assessed using the Adolescent Sedentary Activity Questionnaire (ASAQ) [19]. The ASAQ required respondents to self-report time spent using different screen devices on each day of the week, including weekends. Specifically, participants were asked to report time spent using television, video/DVD, computer, and tablet/smartphone for entertainment purposes on a usual school week. The final item (i.e., tablet/smartphone) was not part of the original ASAQ instrument but was added to reflect current trends in adolescents' screen media use. Mean daily screen-time was calculated by adding the time spent using each screen device on each day of the week and dividing by the number of reported days (i.e., 7). The ASAQ has shown acceptable test-retest reliability among girls (ICC = 0.70, 95% CI: 0.40, 0.85), and boys (ICC = 0.84, 95% CI: 0.69, 0.91) [19].

Secondary outcomes

Weight was measured without shoes, in light clothing using a portable digital scale (Model no. UC-321PC, A&D Company Ltd, Tokyo Japan) and height was recorded using a portable stadiometer (Model no. PE087, Mentone Educational Centre, Australia). BMI was calculated using the standard equation (weight [kg] / height [m]^2) and BMI z-scores were calculated using the 'LMS' method [20]. Physical activity was assessed over 7 days using GENEActiv (Model GAT04, Activinsights Ltd, Cambridge shire England) wrist worn accelerometers, and activity intensity was determined using existing cut-points [21]. Valid wear time was defined as a minimum of 10 hours per day on at least three days. Emotional and behavioral problems were assessed using the Strength and Difficulties Questionnaire (SDQ) [22] and the Kessler Psychological Distress Scale [23] was used to provide a global measure of distress. Physical self-concept was assessed using a subscale from Marsh's Physical Self-Description Questionnaire (PSDQ) [24] and the 'Flourishing Scale' was used to measure participants' psychological well-being in areas such as engagement, relationships, self-esteem, meaning, purpose and optimism [25].

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Hypothesized mediators

The Motivation to Limit Screen-time Questionnaire (MLSQ) [26] was used to assess participants' motivation for limiting their recreational screen-time. The MLSQ contains nine questions relating to the three broad motivational regulations outlined in SDT (i.e., autonomous motivation, controlled motivation, and amotivation) (e.g., *I try to limit my screen-time because my parents pressure me to do so* [18].

Process evaluation

To determine satisfaction and engagement with the S4HM intervention, participants and parents completed a post-program evaluation questionnaire. Using a 5-point scale, students reported: i) how helpful they found the S4HM intervention for reducing screen-time, ii) satisfaction with the school-based interactive seminar, and iii) intentions to decrease screen-time and increase physical activity in the future. Students were also asked to indicate if their parents involved them in setting screen-time rules and creating a screen-time behavioral contract. In addition, students reported on whether their parents read the newsletters, and were asked to identify the most helpful intervention component for reducing screen-time. Parents were asked to evaluate if the S4HM study provided valuable information and useful ideas to limit screen-time. Specifically, parents were asked to comment on and rank the effectiveness of each of the parental support strategies (i.e., setting screen-time rules, screen-time contract, and newsletters).

Statistical analysis

Analyses for the primary and secondary outcomes were performed using IBM SPSS Statistics for Windows version 22 (2010 SPSS Inc., IBM Corp., Armonk, NY), and statistical significance was set at $p < 0.05$. Differences between groups at baseline for those who did not complete follow-up assessments were examined using independent-sample *t*-tests and chi-square (χ^2) tests. Linear mixed models (adjusted for baseline values, sex and participant SES) were used to assess the impact of treatment (S4HM or control), time (treated as categorical with levels baseline and 6-months) and the group-by-time interaction, these three terms forming the base model. Separate models were conducted for the primary and secondary outcomes, which were adjusted for the clustered nature of the data (using a random intercept for school) and included all randomized participants (i.e., intention-to-treat [ITT]). A sensitivity analysis was conducted with completed cases only. However, owing to the high

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retention rate (96%) the results were consistent with the ITT analyses, and are therefore not reported. Multi-level mediation analyses (adjusted for school-level clustering) were conducted using MPlus, version 7.11 for Windows (Muthén & Muthén, Los Angeles, CA). Single and multiple mediator models were tested to assess the potential mediating effects of motivational regulations (i.e., autonomous, controlled and amotivation) on changes in screen-time. Multi-level linear regression analysis provided: (i) the regression coefficients for the treatment effect on the hypothesized mediator at post-test, (Pathway A), (ii) the regression coefficient for the association between the mediator and screen-time at post-test, independent of treatment group (Pathway B), and (iii) estimates of the total intervention effect (treatment predicting screen-time) (Pathway C), and direct effect (total effect adjusted for the mediator) (Pathway C'). In the final stage, the product of the A and B coefficients (i.e., the indirect effect) was computed using Tofghi and Mackinnon's R-mediation package [27]. Significant mediation was established if the confidence intervals for the estimate of the indirect effect (Pathway AB) did not include zero.

Results

Eligibility screening was completed by 1154 students, of whom 935 (81%) were considered eligible. In total, 322 students were recruited and assessed at baseline, with the recruitment target achieved in seven of the eight schools. At post-intervention, 308 students completed follow-up assessments, representing a retention rate of 96%. Baseline characteristics of the study sample are reported in Table 2. There were no significant differences between completers and study drop-outs for any of the demographic variables or study outcomes at baseline ($p > .05$ for all).

Primary outcome

Significant reductions in screen-time were observed in both groups from baseline to post-test (S4HM = -50.5 min/d, $p < 0.001$; Control = -29.2 min/d, $p = 0.030$) (Table 3). However, the adjusted between-group difference was not statistically significant (mean = -21.3 min/d; $p = 0.255$).

Secondary outcomes

There were no statistically significant group-by-time effects for any of the mental health outcomes, BMI or physical activity.

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Mediation analysis

There were significant intervention effects for autonomous and controlled motivation, whereas the effects for amotivation were non-significant (Table 4). Significant associations were observed between changes autonomous motivation and changes in screen-time (B = -17.83, $p < 0.001$). Based on the product-of-coefficients tests, autonomous motivation (AB = -5.40, 95% CI = -12.04 to -0.15) satisfied the criteria for mediation. In the multiple mediator model, only autonomous motivation was found to mediate the effect of the intervention on screen-time (AB = -5.61, 95% CI = -12.59 to -0.10).

Process evaluation

Students reported an overall mean score of 3.5 for the general helpfulness of the S4HM study (possible range = 1 to 5). In general, students identified the messages (39.5%) and the interactive seminar (35.5%) as the most important intervention components. S4HM students reported higher intentions to increase their physical activity (mean = 4.1), compared with intentions to limit screen-time (mean = 3.7). Less than half (43.1%) of participants stated that their parents involved the in setting of screen-time rules, whereas 44.4% reported that their parents set screen-time rules independently. Only 39 parents (23%) completed the evaluation questionnaire, of which approximately one third strongly believed the S4HM intervention provided them with valuable information and useful ideas to limit their child's screen-time. The majority of responding parents (74.4%) believed setting household rules was the most effective strategy to manage screen-time, followed by the behavioral contract (20.5%) and role modeling desired behavior (5.1%).

Discussion

Excessive recreational screen-time is a growing problem in many Western nations, and high levels of screen-time during the developmental years may have lasting adverse effects [28]. Consequently, there is a need for intervention approaches that demonstrate both efficacy and reach. The primary objective of this study was to evaluate the impact of the S4HM intervention on recreational screen-time in a sample of adolescents. Although screen-time declined to a greater extent for the intervention group, the group-by-time effect was not statistically significant. Therefore, our primary hypothesis was not supported. In addition, there were no significant intervention effects for mental health outcomes, physical activity or BMI.

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Although the S4HM intervention was underpinned by theory and utilized novel and scalable intervention strategies, the null findings for screen-time highlight the challenges of influencing adolescents' sedentary behaviors. Indeed, according to a recent review of reviews, the most successful screen-time interventions have been those conducted with young children (i.e., < 6 years) [29]. Relatively few studies have evaluated the effects of screen-time interventions conducted with adolescents; and of those that have, findings have been mixed. The 'Dutch Obesity Intervention in Teenagers' (DOiT) [30] was a multi-component school-based intervention targeting multiple health behaviors among adolescents. The DOiT study was theoretically driven and included both curricular and environmental change strategies. Similar to the present study, no significant intervention effects were reported for screen-time at the 8- and 12-month assessment periods. However, after 20-months a significant effect in favor of the intervention group was found, albeit only for boys (−25 min/d; 95% CI, −50 to −0.3 min/d). In another recent school-based trial [31], significant intervention effects for adolescents' TV viewing and total screen-time were achieved after 18-months of intervention delivery. However, the effects were not maintained once the strategies targeting screen-time were discontinued [31]. Overall, there is a limited understanding of the most effective strategies for reducing screen-time among youth. Consequently, there have been calls for mediation analyses to further elucidate the effects of specific intervention strategies [32].

While the between-group difference for screen-time was not statistically significant, changes did favor the S4HM group. Additionally, the S4HM intervention had a significant impact on autonomous motivation to limit screen-time, which was found to mediate changes in screen-time. It has previously been proposed that changes in motivation are required to influence children's recreational screen-time [33], and evidence supporting the importance of motivation for physical activity behavior [34] lends credence to this suggestion. Given the positive effects on students' motivation in the present trial and the between-group differences favoring intervention students, it is plausible to suggest that the difference between groups for screen-time may increase over time. However, longer term follow-up would be required to determine if this is indeed the case.

Although the intervention had a significant impact on both controlled and autonomous motivation to limit screen-time, only autonomous motivation acted as a significant mediator of changes in screen-time. This further highlights the importance of supporting autonomous rather than controlled motives when targeting health behavior change in this population. Consistent with the tenets of SDT, it appears adolescents are responsive to an approach that acknowledges their desire for autonomy. Future programs could target autonomous

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motivation to reduce screen-time by: (i) providing opportunities for self-evaluation and self-regulation; (ii) clearly describing expected behaviors and providing a rationale for behavior change that is valued by participants [35]; and (iii) supporting individuals in making independent decisions about their behaviors. It is likely that active participation of both youth and their parents in the choice and development of intervention strategies may lead to more acceptable and attractive strategies and thereby more effective interventions [36].

Parents have a significant influence on their children's screen viewing patterns, through the provision of screens in the home, modelling of behavior, co-viewing and enforcement of screen-time rules [37, 38]. Educating parents about screen-time guidelines and prompting them to set screen-time limits have been identified as potential strategies for reducing screen-time among youth [39]. Although parents were targeted in the present trial, lack of engagement may explain the weak study findings. For example, few parents completed the process evaluation questionnaire, and of those that did only one third reported reading the S4HM newsletters. It is unclear to what extent parents implemented the strategies provided within the newsletters. However, given the seemingly low engagement, it is likely that few parents implemented meaningful changes to their screen-time parenting practices. Engaging parents in heath behavior interventions remains challenging and the most feasible and scalable strategies (e.g., sending educational material to the home) also appear to be the least effective [29]. Further research examining how to effectively engage parents is therefore needed.

Although the causal sequencing has not been clearly established, there is emerging evidence suggesting that excessive screen-time during youth may lead to poor mental health outcomes [40, 41]. As there was no significant between-group difference for screen-time in the present trial, the lack of intervention effects for mental health indicators is not surprising. However, there were also no significant within-group effects, despite significant reductions in screen-time for both groups over the study period. In a recent obesity prevention trial with low-income adolescents', changes in screen-time were found to mediate the effect of the intervention on well-being [42], suggesting that reducing screen-time may be a viable strategy for improving adolescents' psychological health . However, participants in the present trial were from more affluent backgrounds, and the majority reported good mental health at baseline. Consequently, there may have been little scope to improve psychological health among this sample.

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Strengths of the present study included the robust study design, objectively measured physical activity and the high retention rate at post-intervention. However, it is important to acknowledge some limitations. First, while all eligible students were invited to participate, the study sample consisted predominantly of girls who identified their cultural background as Australian or European. Therefore, caution should be taken in generalizing the findings to other groups. Second, few parents completed the evaluation questionnaire, making it difficult to determine the extent to which the parent-based strategies were implemented. Finally, the primary outcome measure (i.e., the ASAQ) was subjective, introducing the possibility of recall and social desirability biases. The ASAQ has previously demonstrated satisfactory test-retest reliability, but there is limited evidence regarding the utility of this measure for detecting changes in screen-time in intervention studies. Previous studies have used objective measures such as television monitors to capture screen-time [43]. However, logistical barriers precluded the use of these measures in the current trial. Further, the changing nature of adolescents' screen-use suggests that such measures may miss much of the screen-time that adolescents now engage in (i.e., tablet, smartphone, handheld video games etc.).

Conclusions

Screen use for recreation is ubiquitous and the majority of adolescents exceed current screen-time recommendations [44]. In light of this, there is a clear need for effective and scalable intervention strategies. Despite being theoretically driven, the present trial was ineffective in its primary aim of reducing recreational screen-time. Significant intervention effects were observed for participants' autonomous motivation to limit screen-time, which mediated changes in screen-time. This finding provides support for intervention strategies that enhance autonomous motives for behavior change. However, given the accepted importance of parents in their children's health behaviors, continued research on the most effective methods for engaging parents is warranted.

Competing interests

The authors have no competing interests to declare.

Author contributions

DRL, PJM, RCP, NE, GS, CL and ALB obtained funding for the research. All authors contributed to developing, editing, and approving the final version of the paper. DRL, PJM, RCP, CL, GS and MB developed the intervention materials. MB and EP were

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responsible for data collection and cleaning. DRL is the guarantor and accepts full responsibility regarding the conduct of the study and the integrity of the data. All authors have read and approved the final manuscript.

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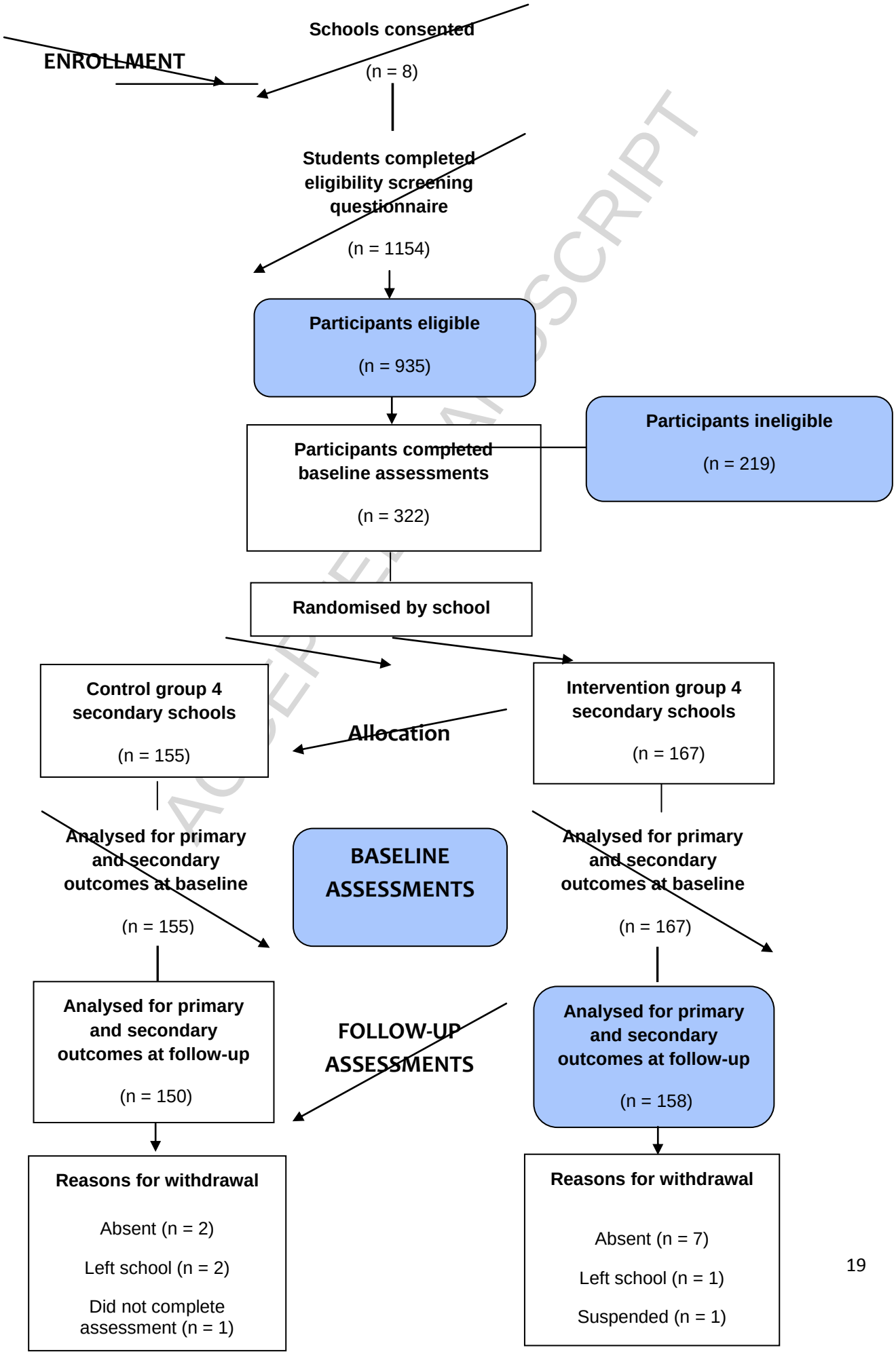
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Figure 1: Study design and flow



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Figure 2: CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1,2
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	4,5
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	3,4
	2b	Specific objectives or hypotheses	4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	4
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	4,8
Participants	4a	Eligibility criteria for participants	4,8
	4b	Settings and locations where the data were collected	4
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	4,5
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	6
	6b	Any changes to trial outcomes after the trial commenced, with reasons	N/A
Sample size	7a	How sample size was determined	4
	7b	When applicable, explanation of any interim analyses and stopping guidelines	7,8
Randomisation:			
Sequence	8a	Method used to generate the random allocation	4

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generation		sequence	
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	4
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	4
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	4
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	N/A
	11b	If relevant, description of the similarity of interventions	N/A
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	7,8
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	7
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	8
	13b	For each group, losses and exclusions after randomisation, together with reasons	18
Recruitment	14a	Dates defining the periods of recruitment and follow-up	4
	14b	Why the trial ended or was stopped	N/A
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	18
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	N/A
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its	23

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		precision (such as 95% confidence interval)	
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	23
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	N/A
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	N/A
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	11
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	11
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	9-12
Other information			
Registration	23	Registration number and name of trial registry	2
Protocol	24	Where the full trial protocol can be accessed, if available	4
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

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Table 1: Intervention components of the S4HM intervention

Intervention component	Dose	Description	Behavior change strategies	Hypothesized mediators
1. Interactive seminar	Delivered to students at their school at the start of the intervention (Approximately 60 minutes)	An interactive seminar was delivered by a member of research team to students during school hours. The session focused on the consequences of excessive recreational screen-time and the benefits of reducing excessive recreational screen-time. Students were given an opportunity to ask any questions and interact throughout the session using Turning point™ interactive polling.	▪ Information on consequences ▪ Prompt intention formation ▪ Provide instruction ▪ General encouragement	▪ Motivation to limit screen-time ▪ Perceived autonomy ▪ Perceived competence ▪ Perceived relatedness
2. EHealth	32 prompts over 6-months were delivered to students Twice weekly	Participants selected their preferred method for receiving eHealth messages from the following options: Twitter,	▪ Provide information about behavior health link ▪ Prompt self-	▪ Motivation to limit screen-time
3. Parental newsletters	6 over 6 months (1 per month). Delivered to parents	Newsletters were printed and posted to parent's home addresses and focused on: household screen-time rules, consequences of excessive screen-time, strategies to manage parent/child conflict arising from screen-time rules and home challenges to reduce recreational screen-time. For example, setting clear rules, placing limits on screen-time, and introduced ideas such as not having screen-based media in bedrooms in order to	▪ Provide information about behavior health link ▪ Prompt self-monitoring of behaviors ▪ Prompt specific goal setting ▪ Information on consequences ▪ General encouragement	▪ Perceived competence ▪ Physical activity behavioral strategies ▪ Motivation to limit screen-time

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			aim and help encourage fewer hours of screen-time in adolescents.		
4.	Behavioral contract	Once. This involved parents and the participants	Students were asked to sign a screen-time behavioral contract in the second month of the intervention. The contract provided described appropriate replacement behavior and encouraged the creation of a list of; potential screen-time rules, benefits of limiting screen-time, possible barriers of limiting screen-time, possible solutions to such barriers and consequences of exceeding screen-time limits. Students were recommended to complete this contract with their parents.	▪ Prompt specific goal setting ▪ Prompt identification as a role model	▪ Motivation to limit screen-time ▪ Perceived autonomy ▪ Perceived competence

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Table 2: Baseline characteristics of the S4HM study sample

Characteristics	Control (n = 155)	Intervention (n = 167)	Total (N = 322)
Age, y, mean, SD [a]	14.33 ± 0.5	14.47 ± 0.6	14.40 ± 0.6
Born in Australia, n	155 (100%)	167 (100%)	322 (100%)
Sex, n			
Female	104 (67%)	107 (64%)	211 (66%)
Male	51 (33%)	60 (36%)	111 (34%)
English language spoken at home, n	150 (97%)	166 (99%)	316 (98%)
Cultural background, n			
Australian	150 (97%)	166 (99%)	316 (98%)
European	3 (2%)	1 (1%)	4 (2%)
African	0 (0%)	0 (0%)	0 (0%)
Asian	2 (1%)	0 (0%)	2 (0%)
Middle eastern	0 (0%)	0 (0%)	0 (0%)
Other	0 (0%)	0 (0%)	0 (0%)
Socioeconomic position, n [b]			
1-2	1 (1%)	12 (7%)	13 (4%)
3-4	34 (22%)	50 (30%)	84 (26%)
5-6	108 (70%)	80 (48%)	188 (58%)
7-8	7 (4%)	18 (11%)	25 (8%)
9-10	5 (3%)	7 (4%)	12 (4%)
Weight, kg, mean, SD [c]	51.20 ± 13.5	51.74 ± 12.5	51.49 ± 12.9
Height, cm, mean, SD [c]	156.08 ± 7.1	157.81 ± 7.4	156.98 ± 7.3
BMI, $kg.m^{-2}$ [d]	20.85 ± 4.5	20.69 ± 3.9	20.73 ± 4.2
Weight status, n			
Underweight	15 (10%)	22 (13%)	37 (12%)
Healthy weight	83 (53%)	84 (50%)	167 (52%)
Overweight	39 (25%)	36 (22%)	75 (23%)
Obese	18 (12%)	25 (15%)	43 (13%)

[a] Abbreviations: y = years, SD = standard deviation

[b] Socioeconomic position determined by population decile using Socio-Economic Indexes For Areas of relative socioeconomic disadvantage based on residential postcode (1 = lowest, 10 = highest).

[c] Abbreviations: SD = standard deviation

[d] Abbreviations: BMI = body mass index, SD = standard deviation

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Table 3: Changes in primary and secondary outcomes in the S4HM intervention

Outcome[s]	Baseline, Mean (CI)	6-month, Mean (CI)	Change, Mean (CI)	*p*	Adjusted difference in change, Mean (CI)	*p*
Screen-time (minutes/day)						
Control	288.88 (197.18, 380.58)	259.67 (167.95, 351.39)	-29.21 (-55.53.72, -2.89)	0.030	-21.27 (-57.98, 15.44)	0.255
Intervention	319.54 (227.91, 411.18)	269.06 (177.40, 360.72)	-50.48 (-76.07, -24.89)	< 0.001		
Psychological difficulties						
Control	15.39 (14.35, 16.42)	14.98 (13.94, 16.01)	-0.41 (-1.01, 0.19)	0.177	0.83 (-0.75, 0.92)	0.845
Intervention	15.40 (14.38, 16.43)	15.07 (14.04, 16.10)	-0.33 (-0.91, 0.25)	0.266		
Psychological distress						
Control	18.53 (16.80, 20.27)	17.75 (16.01, 19.48)	-0.79 (-1.66, 0.08)	0.076	0.20 (-1.01, 1.41)	0.745
Intervention	18.22 (16.50, 19.93)	17.63 (15.91, 19.35)	-0.59 (-1.43, 0.26)	0.173		
Physical self-concept						
Control	27.87 (25.11, 30.63)	27.39 (24.63, 30.15)	-0.48 (-1.47, 0.50)	0.335	0.57 (-0.80, 1.94)	0.410
Intervention	27.79 (25.04, 30.54)	27.89 (25.13, 30.64)	0.09 (-0.86, 1.05)	0.849		
Well-being						
Control	45.72 (43.26, 48.18)	45.98 (43.52, 48.44)	0.26 (-0.99, -1.51)	0.685	-0.60 (-2.34, 1.15)	0.501
Intervention	46.82 (44.37, 49.26)	46.48 (44.03, 48.93)	-0.34 (-1.55, 0.87)	0.584		
MVPA (minutes/day)						
Control	36.55 (32.58, 40.53)	34.54 (30.28, 38.80)	-2.01 (-5.82, 1.80)	0.299	-4.22 (-9.55, 1.11)	0.120
Intervention	36.84 (32.93, 40.76)	30.62 (26.29, 34.94)	-6.23 (-9.95, -2.50)	0.001		
BMI, ($kg.m^{-2)}$						
Control	20.61 (19.07, 22.15)	20.90 (19.36, 22.44)	0.29 (0.13, 0.45)	0.001	-0.02 (-0.25, 0.20)	0.840
Intervention	20.50 (18.96, 22.04)	20.76 (19.23, 22.30)	0.27 (0.11, 0.43)	0.001		
BMIz						
Control	0.51 (0.16, 0.87)	0.42 (0.07, 0.78)	-0.09 (-0.34, 0.16)	0.473	0.09 (-0.26, 0.44)	0.623
Intervention	0.50 (0.15, 0.86)	0.50 (0.15, 0.85)	-0.00 (-0.25, 0.24)	0.972		

Note. BMI = body mass index, CI = 95% confidence intervals, MVPA = moderate-to-vigorous physical activity

114 and 127 students from the control arm recorded valid accelerometer wear time at baseline on weekend days and weekdays, respectively

131 and 137 students from the intervention arm recorded valid accelerometer wear time at baseline on weekend days and weekdays, respectively

96 and 90 students from the control arm recorded valid accelerometer wear time at follow-up on weekend days and week days, respectively

84 and 85 students from the intervention arm recorded valid accelerometer wear time at follow-up on weekend days and week days, respectively

Between group differences reported were adjusted for baseline values, sex and socio-economic status.

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Table 4: Mediation analyses for the single mediator models adjusted for sex and SES

Hypothesized mediators	Treatment on mediators		Mediator on screen-time		Direct effect of treatment on screen-time		Mediated effect
	A (SE)[a]	*p*	B (SE)[b]	*p*	C' (SE)[c]	*p*	AB [95% CI][d]
Autonomous motivation	0.30 (0.15)	0.040	-17.83 (4.26)	< 0.001	-6.68 (23.03)	0.772	-5.40 [-12.04, -0.15]
Controlled motivation	0.32 (0.15)	0.029	-6.04 (6.28)	0.337	-9.64 (23.68)	0.684	-1.93 [-7.52, 2.10]
Amotivation	-0.17 (0.15)	0.058	8.41 (4.44)	0.058	-10.51 (24.46)	0.667	-1.43 [-5.27, 1.11]

Note. SE = standard error, *p* = significance, CI = confidence intervals, RAI = relative autonomy index. Models are adjusted for clustering, baseline values, sex and SES.

[a] A = estimate of standardized regression coefficient of treatment condition predicting change in hypothesized mediators at 6-months

[b] B = estimate of standardized regression coefficient of the relationship between changes in hypothesized mediators at 6-months and changes in screen-time

[c] C' = estimate of standardized regression coefficient of treatment condition predicting screen-time with adjustment for mediator

[d] AB = indirect or 'mediated' effect (product-of-coefficients estimate)

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Highlights

1. Reductions in screen-time were not statistically significant
2. No intervention effects were found for mental health, physical activity or BMI
3. Intervention effect was partially mediated by increases in autonomous motivation

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