Abstract

Purpose: The objective of this investigation was to examine the mechanisms of physical activity and dietary behavior change in the *Program X* intervention.

Methods: *Program X* involved a clustered randomized controlled design with six schools (N = 124 participants, mean age = 14.1 ± 0.8) randomized to intervention or control conditions for the six-month study period. Physical activity and fruit and vegetable consumption were assessed using pedometers and questionnaires, respectively. The theoretical framework of the intervention was assessed using structural equation modeling, mediation and moderation analyses.

Results: The model explained 56% of the variance in physical activity at 6-months, but did not represent a good fit to the data, $\chi^2 = 87.43$, $df = 19$, $p < 0.001$. The model explaining fruit and vegetable consumption explained 31% of the variance and provided a good fit to the data, $\chi^2 = 12.40$, $df = 10$, $p = 0.259$. None of the variables satisfied the criteria for mediation or moderation in the physical activity model, but gender moderated the effects of intervention on fruit and vegetable consumption.

Conclusions: None of the hypothesized mediators were responsible for behavior change in The Program X intervention. Future studies should address the limitations of existing psycho-social scales and continue to explore the mechanisms of behavior change using model testing, mediation and moderation analyses.

Introduction

It is estimated that 155 million children worldwide are overweight or obese [1]. In Australia this translates to approximately a quarter of youth being overweight or obese [2] and similar rates have been observed in the United States [3]. The long-term consequences of childhood obesity are substantial and include an increased risk for adult metabolic syndrome [4], coronary heart disease and stroke [5]. The short-term consequences of obesity are more psychosocial, as obese children become victims of early and systematic discrimination [6].

Schools have been identified as important institutions for the delivery of physical activity and dietary interventions [7], yet their impact on physical activity and dietary behaviors to date has been modest [8, 9]. It has been suggested that the lack of effectiveness of school-based interventions has been compounded by a poor understanding of the mechanisms responsible for behavior change [10].

Despite recommendations that more research be focused on understanding predictors of physical activity and dietary behavior change in interventions [11-13], few studies have explored the mediators and moderators of behavior change in youth [14]. Two recent reviews found only seven studies that had examined mediators of physical activity [14] and nutrition [15] behaviors in youth interventions. In the context of a physical activity intervention, a mediator (e.g. self-efficacy) can be considered as an intervening causal variable necessary to complete the pathway from an intervention to behavior change [11]. Moderators are variables that modify the form or strength of the intervention of the targeted behavioral outcome [16]. The examination of mediators and moderators is necessary for the systematic progression of physical activity and dietary intake research [11] because they can be used to identify the mechanisms of behavior change and allow researchers to develop more parsimonious theoretical models by eliminating unrelated mediators from future interventions [17].

The primary objective of this investigation was to explore the mechanisms of physical activity behavior and dietary behavior change in the *Program X* intervention for adolescents. The

Program X [18] intervention resulted in significant increases in physical activity among boys and girls in the intervention group and positive changes in some dietary outcomes.

Methods

Participants and procedure

The protocol for this study was approved by the University of Newcastle, New South Wales (NSW), Australia and the NSW Department of Education and Training ethics committees. Based on a power calculation, a sample of 120 students (60 in each treatment arm) was necessary to detect an increase in 0.5 standard deviations (1500 steps/day), with 80% power and assuming 5% significance [19]. Eight secondary schools located within 20 minutes drive from the University of Newcastle were invited to participate in the study. Two schools (one government school and one independent school) declined to participate and six schools were randomized. The names of the six schools were placed in an envelope and schools were drawn from the envelope by a member of the research team and alternatively assigned to control or treatment conditions. The intervention was delivered over two ten-week terms. The intervention was offered as an extra-curricular school sport program aimed at, but not restricted to low-active adolescents. The study aimed to recruit 25 students from each of the six schools. A total of 124 students consented to participate in the study, providing a response rate of 83%. Baseline data were collected in May/June 2007 and follow-up data were collected in November/December 2007.

Treatment conditions

A detailed explanation of the *Program X* intervention has been reported elsewhere [18]. In short, the intervention was based on the '*Learning to Enjoy Activity with Friends'* (LEAF) program [20] and was developed in reference to Bandura's Social Cognitive Theory (SCT) [21]. The *Program X* intervention was delivered as an extra-curricular school sport program and involved five major components: i) Enhanced school sport program focusing on

lifetime physical activities, ii) Information sessions and summary interactive lecture, iii) Pedometers for physical activity monitoring, iv) Physical activity and nutrition handbooks with monthly information newsletters for parents, and v) Social support for healthy behaviors via emails. The enhanced school sport component was delivered once a week for ten weeks and focused on lifetime activities (e.g. aerobics, weight training, circuit training). The intervention was designed to target the following mediators of physical activity and dietary behavior change: physical activity self-efficacy, physical activity social support, physical activity self-management strategies, fruit and vegetable availability and fruit and vegetable self-efficacy (Table 1). There is empirical support for self-efficacy as a mediator of physical activity and dietary behavior change in youth [14, 15] and self-efficacy was hypothesized to be the primary mechanism responsible for behavior change in the *Program X* intervention. Students were provided with opportunities to develop confidence, skills and mastery in a range of exercise-based activities and encouraged to exercise with friends and provide modelling and social persuasion. Students used heart rate monitors and Borg's Rating of Perceived Exertion to improve their understanding of exercise intensity because a greater awareness of the physiological symptoms of effort and discomfort may contribute in a positive fashion to exercise adherence [22]. Physical activity and nutrition self-monitoring was included to provide a sense of accomplishment which has been shown to be an important source of efficacy beliefs [23].

Interventions targeting the physical activity and nutrition behaviors of youth are more effective when they include strategies to engage parents [9, 24]. Social support was identified as a key environmental component and the intervention included strategies to elicit social support for physical activity and healthy eating from family members through newsletters and email-based messages. In addition, students were provided with physical activity and nutrition handbooks which included home challenges that required parents to sign-off, to indicate that

students had completed the designated activities.

There is strong evidence supporting the influence of behavioral processes on physical activity among adults [25] and while few studies have explored the importance of behavioral strategies with adolescents [14], there is some evidence to suggest that they should be targeted in adolescent interventions [26]. Participants in the Program X intervention were provided with physical activity and nutrition diaries and pedometers to monitor their behaviors. Although the Program X intervention included information describing the benefits of physical activity and healthy eating, there is little evidence to suggest that outcome expectancies and expectations mediate behavior among adolescents. Therefore, to reduce respondent burden, these were not assessed in the current intervention.

Students assigned to the control group schools participated in the same 10-week enhanced school sport component, but did not receive the additional strategies to support behavior change.

Measures

i) Physical activity: Yamax SW700 pedometers were used in the current study to measure physical activity because they are the most accurate and reliable pedometers commercially available [27].

ii) Fruit and vegetable consumption. Fruit and vegetable consumption was assessed using items from the NSW Schools Physical Activity and Nutrition Survey (SPANS) [28]. Two items were used to assess the students' consumption of fruit and vegetables and students were provided with the following examples '1 serve of vegetables = ½ cup of cooked vegetables or 1 cup of salad vegetables' and '1 serve of fruit = 1 medium piece of fruit (e.g. apple) or 2 small pieces of fruit (e.g. kiwi fruit) or 1 cup of dried fruit'. The items were added together to provide a composite measure of fruit and vegetable consumption.

iii) Hypothesized mediators. A number of potential physical activity and dietary mediators

derived from Bandura's SCT [21] were assessed using a questionnaire. The physical activity mediators were physical activity self-efficacy, family social support, and self-management strategies. The dietary mediators were fruit and vegetable self-efficacy and availability. The scales used in the study were existing validated scales and are summarized in Table 1.

iv) Hypothesized moderators- Two dichotomous variables were tested as potential moderators of the *Program X* intervention: gender and level of cardio-respiratory fitness (CRF) at baseline (low or high). Gender was examined as a moderator of physical activity and dietary behavior change because interventions targeting these behaviors often result in differences for boys and girls [9, 29, 30]. Furthermore, we previously reported a significant increase in fruit intake among girls but not boys in the intervention group [18]. CRF was explored as a possible moderator of physical activity because CRF was associated with physical activity at baseline [31] and previous studies have shown that physical activity interventions involving pedometers for self-monitoring appear to be more effective with low-active individuals [18, 29, 30]. We hypothesized that intervention would be more effective among individuals with low-levels of CRF. The 3-minute Queen's College Step Test was used to provide an estimate of CRF at baseline [32] and the following equations were used to predict maximum oxygen uptake capacity: Girls: VO_2 max (ml/kg/min) = 65.81 - 0.1847 x heart rate (beats/min) and boys: VO_2 max (ml/kg/min) = 111.33 - 0.42 x heart rate (beats/min). The data file was split by gender and subjects in the bottom 50% were classified as low-fit, and participants in the top 50% were classified as high fit.

Analysis

Means, standard deviations and regression models were calculated using SPSS® version 17.0 (SPSS Inc., Chicago IL) and structural equation models (SEM) were tested using AMOS 17.0 (SmallWaters Corp., Chicago IL). Two participants did not complete the questionnaire and were not included in the analyses. Of those who attempted the questionnaire, all participants completed most of the scales. Means of completed items for

each individual were imputed for missing items in scales (less than 2% of items missing for the whole sample).Baseline value carried forward was used for data missing at posttest (16 cases imputed) and alpha levels were set at $p < 0.05$. Three types of analyses were conducted: (i) structural equation modeling [33], (ii) mediation analyses using a product-of-coefficients test [34] and (iii) moderation analyses using change in confirmatory fit index (CFI) [35].

Model testing. The construct validity of the *Program X* intervention was tested using maximum likelihood (ML) analysis with single indicator latent variables to account for measurement error [33] and minimize model parameters. Separate models were tested for physical activity behavior and fruit and vegetable consumption. In SEM, the model is correctly specified and provides a 'good fit' to the data when it reproduces the sample covariance well [36] and the hypothesized pathways are supported by the relationships between variables in the study sample. Model fit was assessed using multiple indices, including chi-square index, goodness-of-fit index (GFI), adjusted goodness-of-fit (AGFI), and root mean square of approximation (RMSEA). The chi-square tests the null hypothesis that the model is a good fit of the data. The GFI provides an estimate of the proportion of variance in the variance-covariance matrix accounted for by the proposed model. GFI scores range from 0 to 1, a score exceeding 0.9 indicates a good fit [33, 37]. The AGFI provides a GFI score adjusted for the number of parameters in the model. The RMSEA estimates closeness-of-fit compared to the saturated model. RMSEA of 0.08, 0.05 and 0 indicates adequate, close and exact fits, respectively [38].

Mediation analyses. A product-of-coefficients test was used to assess single mediator models using ordinary least squares regression in SPSS. This technique was used because it has good statistical power in small samples [34]. Measures of change (i.e. dependent variables and hypothesized mediators) from baseline to 6-month posttest were computed by regressing the posttest values onto their baseline values to create residualized weight change indices [39,

40]. Using residualized change scores addresses the issue of regression to the mean [41] and accounts for the possibility that individuals classified as low-active have greater potential to increase than active individuals. Asymmetric confidence intervals were used to test the significance of the product-of-coefficients tests as they are more accurate than normal confidence limits [42]. To determine whether each variable mediated changes in behavior, the following regression models were calculated. First, the 'total effect' of the intervention on the dependent variable (i.e. physical activity or fruit and vegetable consumption), controlling for baseline was examined (τ). Second, the relationship between treatment allocation and hypothesized mediators was assessed (α). Third, treatment and hypothesized mediators were entered into a regression model predicting the dependent variable (i.e. physical activity or fruit and vegetable consumption) (β). The mediated effect was then calculated by multiplying α and β. In the final step, asymmetric confidence intervals were used to test the significance of the product of coefficients ($\alpha\beta$) using Mackinnon et al.'s PRODCLIN program [43]. If zero is outside the confidence interval, then the mediated effect is statistically significant [16].

Moderation analyses. To test for moderation, multi-group analyses were conducted across groups. The unconstrained model was first run allowing for the relationships between variables to vary as a function of hypothesized moderators (i.e. gender and fitness level). In the constrained model, the pathways from the intervention to the mediators and the dependent variable (i.e. physical activity or fruit and vegetable consumption) and the pathways from the mediators to the dependent variable were held constant. Cheung and Rensvold [35] proposed critical values for ΔCFIs to indicate measurement invariance. A value of $\Delta CFI \leq -.01$ indicates that the null hypothesis of invariance should not be rejected. This method has been shown to be independent of model parameters and sample size [35].

Results

The mean age of participants was 14.1 ($\pm$ 0.8) years and the majority of participants was

born in Australia (94.4%) and spoke English at home (89.5%). The study sample (N =124) included 58 participants (boys = 30, girls = 28) in the intervention group and 66 (boys = 23, girls = 43) in the control group. Two participants did not complete the mediation questionnaire and are not included in the analyses. One hundred and six participants (87%) were assessed at follow-up and baseline values were imputed for 16 participants. The results of the intervention have been described in detail elsewhere [18]. In summary, boys and girls in the intervention group both increased their physical activity by approximately 1000 steps/day ($\tau = 0.40$, $p < 0.001$, 95% CI = 2196 to 4031). Girls in the intervention group increased their consumption of fruit and vegetables by half a serve/day ($p < 0.05$). Baseline and posttest scores for behaviors and hypothesized mediators are reported in Table 2. There were no significant changes in physical activity or dietary behaviors in the control group.

Model testing. The physical activity behavior model (Figure 1) explained 56% of the variance, but did not represent a good fit to the data, $\chi^2 = 87.43$, $df = 19$, $p < 0.001$, GFI = 0.85, AGFI = 0.65, RMSEA = 0.17, [90% CI = 0.154 to 0.21] and NFI = 0.83. Self-management ($r = 0.29$, $p = 0.05$) was associated with physical activity at baseline but not at posttest. Baseline physical activity ($r = 0.58$, $p < 0.001$) and treatment condition ($r = 0.43$, $p < 0.001$) were both significant predictors of posttest physical activity.

The model for fruit and vegetable consumption (Figure 2) explained 31% of the variance and provided a good fit to the data, $\chi^2 = 12.40$, $df = 10$, $p = 0.259$, GFI = 0.97, AGFI = 0.92, RMSEA = 0.05, [90% CI= 0.00 to 0.11] and NFI = 0.93. In this model, fruit and vegetable self-efficacy ($r = 0.25$, $p = 0.03$) was associated with fruit and vegetable consumption at baseline, but not at posttest. Fruit and vegetable availability at posttest ($r = 0.31$, $p < 0.001$) and fruit and vegetable consumption at baseline ($r = 0.41$, $p < 0.001$) were associated with consumption at posttest.

Hypothesized mediators. The effect of the intervention on hypothesized mediators (α)

and the relationship between mediators and dependent variables (β) are reported in Table 3. The intervention did not have a statistically significant effect on any of the hypothesized physical activity mediators and none of the potential mediators were associated with changes in physical activity. Consequently, none of the hypothesized physical activity mediators satisfied the criteria for mediation (Table 3). The intervention did not have a statistically significant effect on any of the hypothesized nutrition mediators, but changes in fruit in vegetable availability were associated with changes in fruit and vegetable intake [β = 0.56 (SE = 0.27), 95% CI = 0.001 to 1.051]. Neither of the hypothesized nutrition mediators satisfied the criteria for mediation in the study sample.

Hypothesized moderators. There was no difference in CFI between the unconstrained (CFI = 0.85) and constrained models (CFI = 0.85) exploring the moderating effects of gender on physical activity. Similarly, there was no difference between the unconstrained (CFI = 0.83) and constrained models (CFI = 0.83) exploring the moderating effects of fitness level. In the model exploring the moderating effects of gender on fruit and vegetable consumption, CFI = 0.94 in the unconstrained model and 0.90 in the constrained model. The ΔCFI (0.04) exceeded the critical value of -.01, suggesting that gender moderated the effects of the intervention on hypothesized mediators and fruit and vegetable intake.

Discussion

The objective of this paper was to explore the mechanisms of behavior change in the *Program X* school-based intervention for adolescents. The physical activity model did not provide a good fit to the data and the intervention did not impact upon hypothesized mediators. Conversely, the fruit and vegetable model provided an excellent fit to the data but fruit and vegetable self-efficacy and availability did not satisfy the criteria for mediation. Gender moderated the effect of the intervention on fruit and vegetable intake, as girls in the intervention group increased their fruit and vegetable consumption over study period, while boys' fruit and vegetable intake remained stable.

Previous studies exploring the mechanisms of behavior change in physical activity interventions have produced conflicting results [14]. Interventions have had little effect on interpersonal [40] and behavioral mediators [44]. However, there is some evidence to suggest that self-efficacy should be targeted in physical activity interventions among youth [14]. In the current study, none of the hypothesized physical activity mediators satisfied the criteria for mediation. We offer a number of possible explanations to explain the lack of effects on the hypothesized mediators. Construct measurement error has been identified as an issue contributing to the failure of physical activity interventions to detect changes in the determinants of physical activity [14, 45]. While the scales used in the current study demonstrated acceptable consistency over time, many of the items included in the scales did not adequately reflect the intervention components designed to change behavior. Furthermore, the scales used were developed for Northern American adults and adolescents. Consequently, there is a need to ensure that interventions operationalize all scale items and that culturally appropriate scales for specific populations are used. Finally, the measurement sensitivity of our scales may also explain the failure of our study to establish mediation effects.

Another possible explanation for the small changes identified in physical activity mediators relates to *response shift theory* [46]. According to this theory, changes in a measured variable (e.g. physical activity) are accompanied by changes in an individual's self-evaluation and/or internal standard (e.g. self-efficacy) [47]. In the current study, it is possible that participants in the intervention group were confident in their ability to overcome perceived barriers at baseline. However, after completing the program they may have recognized the potential difficulties to maintain their step targets in the future and/or they encountered new barriers relating to being more active. Similarly, ceiling effects might also explain our failure to identify significant changes in the mediators of physical activity behavior. Participants in both intervention and control groups reported relatively high scores

(Mean = 3.5 out of 5) on all physical activity mediator scales at baseline.

Gender and fitness level did not moderate the effects of the *Program X* intervention on physical activity. A common criticism of interventions is that they have shown little consistency in helping those who need it the most [48]. In the current study, both boys and girls in the intervention group increased their physical activity over the study period and the intervention effect sizes were larger among those least active at baseline [18]. This finding corresponds with previous pedometer-based interventions [30, 49, 50], which appear to be more successful with the low-active individuals, including adolescent girls.

The fruit and vegetable model provided an excellent fit to the data but fruit and vegetable self-efficacy and availability did not satisfy the criteria for mediation. Furthermore, changes in availability were in the opposite direction to that hypothesized. Heightened awareness among intervention participants might account for this finding. For example, at baseline, both intervention and control group participants might have paid little attention to the availability of fruit and vegetables in their house. However, following the intervention, it is plausible to suggest that students in the intervention group increased their awareness of the availability or lack of fruit and vegetables in their households. Nevertheless, the study results suggest that the intervention did not impact upon the availability of fruit and vegetables in the participants' households. Additional strategies are needed to engage parents in physical activity and dietary interventions targeting their adolescents. Reynolds and colleagues [51] found that knowledge, self-efficacy and parent consumption partially mediated fruit and vegetable consumption in their school-based dietary intervention. However, their participants were elementary-age children, who have less autonomy over their dietary behaviors, compared to adolescents. Similar to the current study, Haerens et al. [39] failed to identify psycho-social mediators of fat intake following their 1-year physical activity and nutrition intervention for adolescents.

Both males and females increased their vegetable intake over the study period, however, the changes observed among females were larger and a significant moderation effect for gender was identified. A review of moderators in environmental interventions targeting physical activity and nutrition found that gender was the most often assessed moderator [13].

Study strengths and limitations

This is one of the first studies to examine potential mediators of behavior change using an objective measure of physical activity and appropriate statistical analyses were employed. There are some study limitations that should be noted. First, a submaximal test was used to provide an estimate of cardio-respiratory fitness. However, the results the Queen's College Step Test compare favourably with actual VO_2 max values [32] and the Queen's College Step Test can be completed by most participants as long as they adhere to the stepping pace. Second, schools were the unit of randomization and we did not account for the potential clustering of effects in the analysis. Third, we did not assess nutrition self-management and this construct should be examined in future trials. Finally, future studies should consider extending this research with larger sample sizes to further explore the generalizability of the study findings.

Conclusions

Although participants in the *Program X* intervention increased their physical activity and girls increased their consumption of fruit over the six-month study period, none of the hypothesized mediators could explain behavior change. Gender moderated the intervention effect on fruit and vegetable intake but not on physical activity behavior, suggesting that interventions to change nutrition behavior in adolescents may require different strategies for boys and girls. Mediation analyses have the potential to extend our understanding of behavior change in interventions and the results should be reported even in the presence of null findings [15]. The results from the current study emphasize the importance of using scales

developed for specific populations that reflect the intervention components. To the authors' knowledge no existing SCT scales reflect the importance of technology in the lives of young people and the development of such scales is a research priority. Finally, we recommend that researchers develop their physical activity and nutrition interventions in reference to a theoretical model which is tested along with mediators and moderators using the methods outlined in this study.

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