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Mid-intervention mediating effects on children's physical activity in the Transform-Us! cluster-randomized controlled trial

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Abstract

Background/Aim: To investigate the interpersonal and physical environment mediators of the Transform-Us! mid-intervention effects on physical activity (PA) during recess and lunchtime.

Methods: Transform-Us! is a clustered randomized school-based intervention with four groups: sedentary behavior intervention (SB-I), PA intervention (PA-I), combined PA+SB-I and control group. All children in Grade 3 from 20 participating primary schools in Melbourne, Australia were eligible to complete annual evaluation assessments. The outcomes were the proportion of time spent in moderate-to-vigorous PA (MVPA) and light PA (LPA) during recess and lunchtime assessed by accelerometers. Potential mediators included: perceived social support from teachers; perceived availability of line markings; perceived accessibility of sports equipment; and perceived school play environment. Generalized linear models were used and mediation effects were estimated by product-of-coefficients (axb) approach.

Results: 268 children (8.2 years, 57% girls at baseline) provided complete data at both time points. A significant intervention effect on MVPA during recess in the SB-I and PA-I groups compared to the control group (proportional difference in MVPA time; 38% and 40%, respectively) was found. The perceived school play environment was significantly positively associated with MVPA at recess among girls. An increase in perceived social support from teachers suppressed the PA+SB-I effect on light PA during recess (axb= -0.03, 95%CI:-0.06, -0.00). No significant mediating effects on PA during recess and lunchtime were observed.

Conclusions: A positive perception of the school play environment was associated with higher MVPA during recess among girls. Future studies should conduct mediation analyses to explore underlying mechanisms of PA interventions.

Introduction

Childhood obesity is a global phenomenon (1), and physical activity (PA) is an important modifiable determinant to target in prevention interventions (2). Ecological models acknowledge that behavior, including PA, is influenced by environmental factors (3). Environmental influences on behavior are particularly important for children due to lower autonomy in their behavioral decisions (4). Since children spend nearly half of their waking hours at school, this setting provides a potential opportunity for making environmental changes to influence children's PA (3). Changes in the physical environment at school, e.g., facility and equipment provision, have shown favorable effects on children's PA (5,6). Considering that most children have recess and lunchtime every school day, changes in their PA during these periods could make a significant contribution to their overall PA levels (7,8).

Most school-based obesity prevention and PA promotion studies focus on evaluating whether an intervention worked or not. Few studies have examined how, why and for whom interventions worked (9). These issues can be explored with mediation and moderation analyses. A mediator is an intervening causal variable that lies between a predictor and the outcome (10). An intervention may increase participants' PA, for example, via increasing social support for being active (Figure 1). Moderators are variables that may enhance, reduce or directionally change the predictor-outcome relationship (9). Sex is a frequently studied moderator in childhood obesity prevention interventions, with girls generally shown to benefit more from interventions than boys (11).
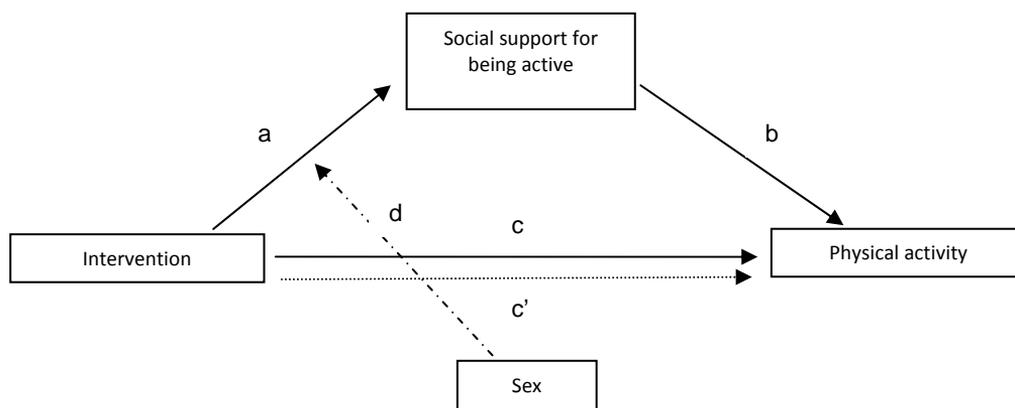

Figure 1. Mediating effect of social support and moderating effect of sex. a: intervention effect on the mediator; b: effect of the mediator on outcome variable while controlling for the intervention effect ; c: overall intervention effect on the outcome variable; c': direct effect of intervention on the outcome variable while controlling for the mediator variable; d: moderating effect of sex on the intervention effect on social support.

Transform-Us! (T-Us) is a cluster-randomized controlled trial aiming to increase children's PA and decrease their sedentary behavior through a behavioral and environmental intervention in the school and family settings in Melbourne, Australia (12). T-Us is based on social cognitive theory (13), behavioral choice theory (14) and ecological systems theory (15). This paper investigated whether key intervention components, interpersonal (social support from teachers) and environmental (availability of line markings, accessibility of sports equipment, perceived school environment) factors mediated the mid-intervention effect of the T-Us intervention on objectively measured PA during recess and lunchtime. The potential moderating effect of sex on the intervention effects on the potential mediators was also examined. Exploring mid-intervention mediating mechanisms is useful for determining whether the study is meeting its aims and objectives.

Methods

Sample

Schools with enrolments >300 students, with at least two Year 3 classes, and within a 50km radius (31 miles) of Melbourne, Australia were selected from low and mid-high socioeconomic strata (SES) (based on the suburb socioeconomic index for areas score) and randomly ordered (12). Eight out of 41 schools in the low SES areas and 12 out of 96 schools in the mid-high SES areas agreed to participate. All year 3 children (n=1606) and their parents at participating schools received the program. As required by ethics, parents signed a consent form for their child to participate in the study evaluation assessments; a total of 599 parents provided consent (Figure 2). The study was approved by the Deakin University Human Research Ethics Committee, the Victorian Department of Education and Early Childhood Development and the Catholic Education Office. Sample and recruitment details are described elsewhere (12).

Intervention

The T-Us is a four-arm cluster-randomized controlled trial (five schools per intervention arm) with a 2x2 factorial design consisting of an 18-month intervention and 12-month booster maintenance periods. Using computer-generated blocks of four, schools were randomly assigned by the project coordinator to one of four groups: physical activity intervention (PA-I); sedentary behavior intervention (SB-I); combined intervention (PA+SB-I); or usual care control (C). This paper focuses on children's PA only as the mediators of interest are specific to PA. However, it is important to include all intervention groups even those with no focus on PA. Possible subsidiary effects may occur in these groups, such as increasing PA as a result of reducing SB. Intervention components are presented in Table 1 (12).
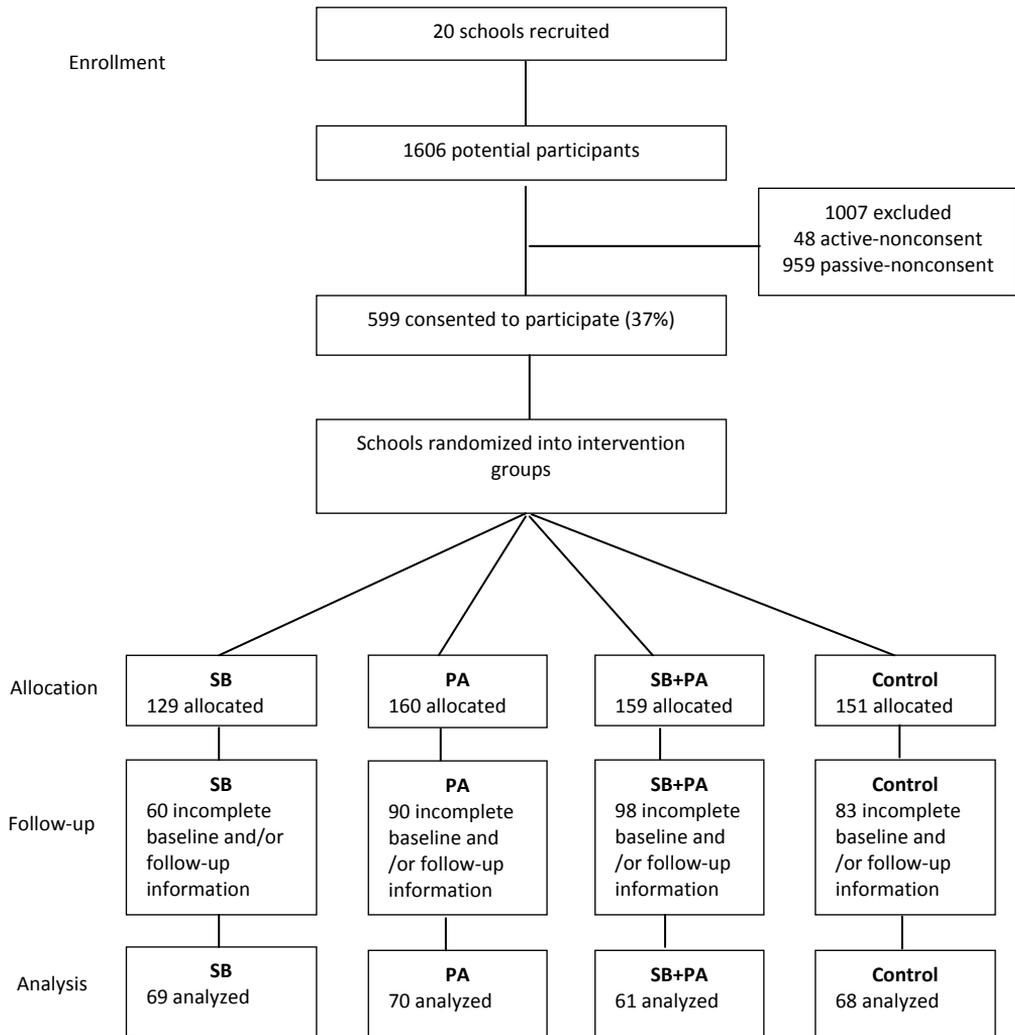
Figure 2. Flow of participants through the intervention

Table 1. Intervention components of the Transform-Us! Study.

Intervention arm	Components
PA-I	Teachers delivered nine educational curriculum sessions including the use of pedometers; children were provided with sports equipment (e.g., balls, bats); were encouraged and supported by peers and teachers to engage in active games during recess and lunchtime; line markings were painted on the schools' playgrounds; and signage promoting PA was placed around the school grounds. Nine family newsletters were sent home that included project updates and tips to increase children's PA at home, and teachers assigned active homework tasks (e.g., going for a walk with the mother or father)
SB-I	Teachers delivered a 30-minute standing lesson daily; each class was provided with four standing easels to assist with standing during lessons; during 2-hour teaching blocks teachers asked the children to stand after 30-minutes for a 2-minute light intensity activity break (prompted by a 'Timer Teddy' provided to each class). Nine family newsletters were sent home, and weekly homework tasks (e.g., switch off the TV for a whole weekend day) to decrease sitting time at home were set by teachers
PA+SB-I	This group received a blended version of the PA-I and SB-I intervention arms with the same total intervention dose
C	Schools in the control group continued their usual practice

PA-I: Physical activity group; SB-I: Sedentary behavior group; PA+SB-I: Physical activity and sedentary behavior combined group; C: control, usual practice group.

Measures

For the current study only baseline and mid-intervention (5-9 months post-baseline) data were used. Baseline data were collected February-July 2010 and mid-intervention data November-December 2010. Children completed questionnaires at school in small groups supervised by trained research staff. Parent questionnaires were self-completed at home.

Physical activity

PA was measured objectively using ActiGraph-GT3X accelerometers (16). Participants wore accelerometers on a belt over the right hip for eight consecutive days during waking hours at baseline and mid-intervention. Data were collected using the uniaxial function and 15-second epochs. Non-wear time was defined as ≥20 minutes of consecutive zero counts. Freedson's age-adjusted cut-points were used to categorize children's PA into light-intensity (LPA; >100cpm – 3.9 METs), moderate-intensity (4-5.9 METs) and vigorous-intensity PA (≥6 METs) (17,18). Data from the school recess and lunchtime periods were extracted based on bell times provided by schools. The average recess and lunchtime durations were 31 (±5 min) and 53 (±10 min) minutes, respectively. The outcome variables included the average proportion of time spent in LPA and moderate-to-vigorous-intensity PA (MVPA) during recess and lunchtime on weekdays (excluding eating time). Children were required to have data for at least 50% of the recess and lunchtime periods on at least three weekdays to be included in analyses (7). As PA data were collected during different seasons at baseline and mid-intervention, maximum temperatures at measurement occasions were used as covariates (19), derived from an online weather service (http://www.tutiempo.net/en/ Climate/).

<u>Potential mediators</u>

Interpersonal

Social support from teachers: Five items (yes/no responses) asked the children whether the class teacher comes outside with them, plays games with them, watches them play games, rewards or praises them for playing active games, and encourages them to play active games. The total score ranged from 0-5 (sum of the 'yes' answers), with higher scores indicating more social support from the teacher. One week test-retest reliability for these items ranged between Kappa=0.2 to 0.7 and percent agreement=70 to 87%.

Environmental

Perceived school play environment: Children were asked to report how much they liked the areas to play in at their school using a 5-point Likert-type scale ranging from 'really dislike' (score= -2) to 'really like' (score= 2). One week test-retest reliability for this item was Kappa=0.2 and percent agreement=83%.

Perceived availability of line markings: A single item asked children to report (yes/no) whether their school has line markings on the walls or playground to help them play games (e.g., 4-square, target on the wall). One week test-retest reliability for this item was Kappa=0.8 and percent agreement=97%.

Perceived accessibility of sports equipment: A single item asked children to report (yes/no) whether they are allowed to use school sports equipment during recess and lunchtime. Kappa values could not be computed due to lack of variability in responses but percent agreement was 100% for one week test-retest reliability.

<u>Demographics and weight status</u>

Children's sex and age were self-reported. Parents (either mother or father) reported their highest level of schooling (as a proxy of socioeconomic status), which was grouped into three categories: <12 years of schooling, 12 years of schooling, and university. Weight status of children at baseline was determined from body mass index (BMI) based on measured weight (using portable electronic Wedderburn Tanita scales) and height (using SECA portable stadiometers). Children were categorized as overweight/obese or normal weight based on international definitions (20).

Statistical Analyses

Only cases that provided complete data for all variables of interest at both time points were included. All analyses were performed using generalized linear models (GLM) and adjusted for clustering within schools. Differences at baseline between the study groups were estimated. Drop-out selectiveness was assessed for sex, intervention status, parental education level, baseline values of PA, and mediators.

PA outcome data were positively skewed, therefore GLMs were used with gamma variance and logarithmic link function to indicate the proportional difference in PA variables between each intervention group and the control group. For binary outcomes logistic regression models were used, and odds ratios (OR) were reported. Maximum temperature at measurement occasions, sex (when it is not a moderator), baseline BMI

and baseline values of outcome and/or mediator (where appropriate) were added as covariates.

Mediation analyses

The effects of the interventions on the outcomes were tested while controlling for baseline outcome measures and relevant covariates. The same applied to the intervention effects on the mediators. Mediation analyses were conducted in 4 steps (21);

1. Total intervention effect on PA outcomes were calculated (path c, Figure 1),
2. Action Theory Test; intervention effect on potential mediators were tested (path a, Figure 1). The moderating effect of sex on these intervention effects was estimated by adding Sex by Intervention group interaction terms. In cases of significant interaction further exploratory subgroup analyses were conducted on both path a and path b, to be able to calculate mediated effects in boys and girls separately,
3. Conceptual Theory Test; the relationship between potential mediators and PA outcomes was estimated (path b, Figure 1), while adjusting for the intervention effect on the PA outcome variable (c' path, Figure 1).
4. The mediated effect was calculated with the product-of-coefficients test (path a x path b) (21). The statistical significance of the mediating effect was established by calculating asymmetric confidence intervals using the FORTRAN program called PRODCLIN (22).

Sample size calculation for the mediation analysis (based on a simulation study from Fritz et al (23)) indicated that to detect a moderate mediated effect with 0.05 significance level and 0.80 level of power, with the PRODCLIN method requires a sample size of 74 (without accounting for clustering in schools). Assuming a commonly-observed school clustering effect of 5% [intraclass correlation (ICC) = 0.05], the sample size required was 'standard sample size' * [1 + (number of observations per cluster – 1) * ICC] = 74 * [1 + (20 schools-1) * 0.05] = 74 * 1.95 = 144.

For all analyses, the statistical significance level was set at $p < 0.05$, except moderation tests where significance was set at $p<0.10$ due to low statistical power for moderation analyses (24).

Results

Participant Characteristics

A total of 268 children (out of 599) provided complete data for all variables of interest at both baseline and mid-intervention (Figure 2). The major reason for excluding children from the final analysis was not having adequate accelerometer wearing time either at baseline or mid-intervention. However, baseline values of PA and mediators, sex, intervention status, parental education level were not related to dropping out at mid-intervention. The mean age of children was 8.2 years, 43% were boys, 48% of responding parents had a university education, and 22% of the children were overweight/obese at baseline. There were no significant differences between the intervention groups and control group at baseline for sex, age or parental education level except BMI and proportion overweight/obese (as shown in Table 2).

Table 2. Baseline characteristics of the Transform-Us! study participants shown as means (standard deviation) or as percentages.

	PA-I (n=70)	PA+SB-I (n=61)	SB-I (n=69)	C (n=68)	TOTAL (n=268)
Age (years)	8.2 (0.4)	8.2 (0.5)	8.2 (0.5)	8.1 (0.3)	8.2 (0.4)
Sex (girl%)	57	54	65	53	57
BMI (kg/m^2)	16.8 (2.6)	17.5 (2.5)	18.5 (5.6)	17.4 (2.7)	17.5 (3.7)
Overweight/obesity status (%)	15	20	30	24	22
Parental education level (%)					
<12 years	16	17	13	14	15
=12 years	28	41	35	46	37
University	56	42	52	40	48

BMI=body mass index, PA-I: Physical activity group; SB-I: Sedentary behavior group; PA+SB-I: Physical activity and sedentary behavior combined group; C: control, usual practice group
No significant differences between the intervention groups and control group except BMI and overweight/obesity status, p<0.05, based on GLM models adjusted for clustering within schools

Table 3 shows the proportion of time spent in MVPA and LPA during recess and lunchtime as well as the hypothesized mediators from both baseline and mid-intervention. There were no significant baseline differences between the intervention groups and control group except lunchtime LPA (Table 3).

Table 3. The proportions of recess and lunchtime physical activity and mean (standard deviation) and percentages of potential mediators at baseline (T1) and mid-intervention (T2).

	PA-I (n=70)		PA+SB-I (n=61)		SB-I (n=69)		C (n=68)		Total (n=268)	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
Outcome variables %										
-Recess MVPA	27	29	33	28	26	28	28	22	28	26
-Recess LPA	38	44	39	39	39	41	39	38	39	41
-Lunchtime MVPA	29	22	32	29	28	21	33	24	30	24
-Lunchtime LPA	41	40	38	41	42	40	41	40	40	40
Potential Mediators										
Social support from teachers [a]	1.5 (1.4)	1.9 (1.4)	1.8 (1.4)	2.5 (1.5)	2.0 (1.3)	1.8 (1.7)	1.9 (1.3)	1.3 (1.4)	1.8 (1.4)	1.9 (1.5)
Perceived availability of line markings (% yes)	53	71	57	67	44	68	74	75	57	71
Perceived accessibility of sports equipment (% yes)	84	99	77	95	90	91	91	100	86	96
Perceived school environment [b]	1.5 (0.8)	1.4 (0.8)	1.5 (0.8)	1.5 (0.7)	1.4 (1.4)	1.3 (0.9)	1.4 (0.8)	1.4 (0.8)	1.5 (1.0)	1.4 (0.8)

PA-I: Physical activity group; SB-I: Sedentary behavior group; PA+SB-I: Physical activity and sedentary behavior combined group; C: control, usual practice group,
MVPA=moderate-to-vigorous physical activity, LPA=light physical activity
a= ranged between 0 to 5, the higher values indicate more perceived social support
b=ranged between -2 to 2, higher positive scores indicate better perceived school environment
No significant baseline differences between the intervention groups and control group except lunchtime LPA, p<0.05, based on GLM models adjusted for clustering within schools
Baseline values of PA and mediators, sex, intervention status, parental education level were not related to dropping out at mid-intervention

Mediation analyses

Intervention effect on PA during recess and lunchtime (c-path)

At mid-intervention, PA-I and SB-I groups had significantly higher MVPA levels during recess compared to the C group (Table 4). Furthermore, children's LPA during recess was significantly higher in the PA-I group compared to the C group. There were no significant differences in lunchtime PA levels between the intervention groups and the C group at mid-intervention (Table 4).

Table 4. Intervention effect on physical activity during recess and lunchtime compared to control group (path *c*).

	PA-I (n=70) b (95% CI)	PA+SB-I (n=61) b (95% CI)	SB-I (n=69) b (95% CI)
Recess MVPA	**1.40***(1.20, 1.62)	1.19 (0.99, 1.44)	**1.38***(1.21, 1.57)
Recess LPA	**1.18***(1. 07, 1.31)	1.03 (0.92, 1.15)	1.08 (0.98, 1.19)
Lunchtime MVPA	0.99 (0.85, 1.15)	1.22 (0.94, 1.58)	0.98 (0.81, 1.19)
Lunchtime LPA	1.00 (0.93, 1.07)	1.03 (0.95, 1.12)	0.99 (0.91, 1.07)

PA-I: Physical activity group; SB-I: Sedentary behavior group; PA+SB-I: Physical activity and sedentary behavior combined group,
b is a regression coefficient of an intervention group with respect to PA variables. It is reported (also 95% CI) as the antilogarithms of the regression coefficients (b) and their 95% CI. They indicate the proportional difference in time spent in PA during recess and lunch between a specific intervention group and the control group at mid-intervention, with values >1 yield a positive and <1 a negative proportional difference. All models adjusted for sex, maximum temperature at baseline and mid-intervention, baseline BMI, baseline value of the outcome variable and school cluster effect.
MVPA=moderate-to-vigorous physical activity, LPA=light physical activity, 95%CI= 95% Confidence interval.
*p<0.05

Intervention effect on potential mediators (a-path)

As shown in Table 5, there was a significant positive mid-intervention effect on perceived social support from teachers in the PA-I and PA+SB-I groups. Sex moderated the intervention effect on perceived school environment in the PA-I and SB-I groups. Among boys the intervention had a negative effect on perceptions of the school environment (the areas to play in at school), whereas among girls the intervention effect was positive. There was no significant intervention effect on the perceived availability of line markings or perceived accessibility of sports equipment (Table 5).

Effect of potential mediators on PA during recess and lunchtime (b-path)

Table 6 shows the relationship between the hypothesized mediators and PA during recess and lunchtime, adjusting for intervention group. There were significant inverse relationships between social support from teachers and LPA during recess, and between perceived availability of line markings and LPA during recess and lunchtime. There was a significant positive relationship between the perceived school environment and MVPA during recess (Table 6). After stratification, this relationship was evident for girls only.

Table 5. Mid-intervention effects on mediators (path *a*).

	PA-I (n=70)		PA+SB-I (n=61)		SB-I (n=69)	
	b (SE) / OR	95% CI	b (SE) / OR	95% CI	b (SE) / OR	95% CI
Social support from teachers	b **0.79*** **(0.34)**	0.13, 1.45	b **1.27*** **(0.40)**	0.49, 2.05	b 0.45 (0.33)	-0.20, 1.11
Perceived availability of line markings	OR 1.23	0.44, 3.49	OR 0.81	0.29, 2.26	OR 0.97	0.33, 2.80
Perceived accessibility of sports equipment	OR 1.09	0.05, 24.8	OR 0.44	0.04, 4.81	OR 0.16	0.02, 1.23
Perceived school environment	b 0.12 (0.07)	-0.01, 0.25	b 0.10 (0.09)	-0.06, 0.27	b -0.13 (0.15)	-0.43, 0.17
- Boys	b -0.03 (0.13)	-0.29, 0.23	-	-	b **-0.92*** **(0.23)**	-1.37, -0.48
- Girls	b 0.27 (0.14)	-0.001, 0.54			b 0.37 (0.20)	-0.03, 0.77

PA-I: Physical activity group; SB-I: Sedentary behavior group; PA+SB-I: Physical activity and sedentary behavior combined group,
b=represents the estimated difference in potential mediator's scores between a specific intervention group compared to the control group.
OR=represents the proportional difference in odds of a positive perception on availability of line markings or accessibility of sports equipment between a specific intervention group and the control group.
OR=Odds ratio, SE=Standard error, 95%CI= 95% Confidence interval
All models adjusted for sex, maximum temperature at baseline and mid-intervention, baseline BMI, and baseline value of the outcome variable and school cluster effect.
*p<0.05

Table 6. Effect of potential mediators on recess and lunchtime physical activity –single mediator tests (path *b*).

	Recess MVPA b (95%CI)	Recess LPA b (95%CI)	Lunchtime MVPA b (95%CI)	Lunchtime LPA b (95%CI)
Social support from teachers	0.97 (0.92-1.01)	**0.98*** (0.96, 0.99)	0.98 (0.94, 1.03)	0.99 (0.98, 1.02)
Perceived availability of line markings	1.01 (0.90, 1.12)	**0.95*** (0.90, 0.99)	0.95 (0.88, 1.02)	**0.95*** (0.91, 0.98)
Perceived accessibility of sports equipment	1.11 (0.89, 1.38)	0.99 (0.91, 1.09)	1.16 (0.91, 1.49)	0.95 (0.88, 1.04)
Perceived school environment	**1.06*** (1.01-1.12)	1.01 (0.99, 1.04)	1.01 (0.96, 1.07)	0.99 (0.97, 1.02)
- Boys	0.99 (0.90, 1.10)	0.99 (0.95, 1.05)	0.96 (0.86, 1.06)	0.99 (0.95, 1.03)
- Girls	**1.13*** (1.07, 1.19)	1.03 (0.99, 1.07)	1.06 (0.99, 1.13)	0.99 (0.97, 1.03)

b is a regression coefficient of a potential mediator with respect to PA variables. It is reported as the antilogarithm of the regression coefficient. It indicates the proportional difference in time spend in PA during recess and lunch for each one unit increase in the potential mediators, with values >1 a positive and <1 a negative proportional difference.
MVPA=moderate-to-vigorous physical activity, LPA=light physical activity, 95%CI= 95% Confidence interval
All models adjusted for sex, maximum temperature at baseline and mid-intervention, baseline BMI, school cluster effect, intervention groups and baseline values of the outcome and the mediator variable
*p<0.05

Mediated effects

There were no significant mediated effects. There was a significant suppression effect of social support from teachers on the intervention effect on children's LPA during recess in the PA+SB-I group (online Appendix 1 and Figure 3). This means that more social support from the teacher was associated with less LPA during recess.
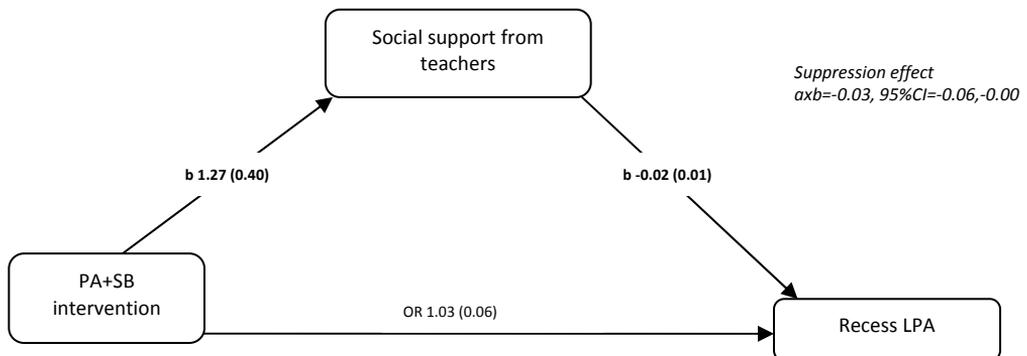
Figure 2. Suppression effect of social support from teachers on the intervention effect on light physical activity (LPA) at recess among physical activity and sedentary behaviour (PA+SB) combined group.

Discussion

To our knowledge, this is the first study that examined the mediating mechanisms of an intervention effect on PA during school recess and lunchtime. Both the PA-I and SB-I showed significant positive effects on MVPA during school recess; the PA-I also had a significant mid-intervention effect on LPA during recess. There were no significant mediating effects.

The school environment (e.g., area type, area size) has previously been shown to be an important factor influencing children's PA at recess and lunchtime (5,25,26). In the current study children's liking of the school play environment was significantly positively related with MVPA during recess among girls. We also found a moderating effect of sex on the effect of the SB-I and PA-I intervention on perceived school environment, with negative intervention effects among boys and positive effects among girls. In general boys are more dominant in the school playground during school breaks (27), but the changes in the school play environment as part of T-Us might have been appreciated by girls due to having more playground space for play. A previous school-based intervention implemented by Ridgers et al. (28) aimed at increasing PA during recess by redesigning the school playground environment using playground markings and physical structures showed favorable effects on PA levels during recess-lunchtime combined over time. They found that initial changes in the physical environment had a positive impact on children's PA. Another school-based recess intervention highlighted the effectiveness of providing sports equipment to increase children's PA during recess (29). In the current study perceived accessibility of sports equipment was not significantly associated with MVPA during recess and lunchtime, possibly because children in all groups had access to such equipment. Most of the children reported favorably on the accessibility of sports equipment at baseline, which could have produced a ceiling effect, leaving limited room for improvement in the perception of accessibility of sports equipment.

An unexpected finding was that perceived social support from teachers appeared to suppress the intervention effect on recess LPA in the PA+SB-I group. Children who

perceived more social support from teachers had lower LPA during recess. A possible reason for this could be that teachers were encouraging children to do more structured, organized activities that might not be attractive to children resulting in lower levels of PA. It has been shown that children are more likely to participate in PA in unstructured play settings (30). Children in the PA+SB group received all the intervention strategies, i.e. reducing sitting during class, and promoting PA during recess and lunchtime. Teacher support both during classes and school breaks might be perceived as too much control over child's behavior since recess may be viewed by children as 'their time' and teacher interactions might be perceived as playground discipline (31). Furthermore, in this age group children are likely to be more sensitive to social support from their peers rather than adults (32).

Another unexpected result was that the line markings were significantly inversely related to LPA during recess and both MVPA and LPA at lunchtime. This suggests that at the mid-intervention point, the selected line markings were not effective in increasing children's activity during their recess and lunchtime. Process evaluation found that schools in the SB and C groups reported that they had additional line markings painted in the school grounds during the intervention period even though this was not promoted by the T-Us intervention for these groups.

Strengths of the current study include being the first study to explore the underlying mechanisms with mediation analysis of mid-intervention effects on PA change during recess and lunchtime, and the measurement of PA by accelerometry. We explored the mid-intervention effects on LPA in addition to MVPA during recess and lunchtime. Studying changes in LPA may be important in terms of children's daily energy expenditure and increases in PA may not always be at a moderate or vigorous intensity. However, there were some limitations, such as the self-reported measurement of the mediators, which is subject to socially desirable response bias; and the potential low sensitivity to change of these measures. Some mediating variables had low Kappa value (despite showing high percent agreement), which generally happens due to instability in the Kappa statistic as a result of having a high percent of responses in one category (33). The perceived school environment was measured by a single item, which prevented us exploring more detailed aspects of its influence on PA change during recess and lunchtime. Low reliability of some of the mediator measures may also be one of the reasons for the lack of significant mediated effects. The intervention strategies might not be adequately implemented or might not be the right ones for changing the potential mediators. Furthermore, there could be other potential mediators not assessed in this study that may explain children's recess and lunchtime PA.

Contributions and future research

To our knowledge previous PA intervention studies have not explored the mediation mechanisms of their effects on children's PA during recess and lunchtime. There is a current shift in PA research towards ecological models, which emphasize that behavior is influenced by the physical environment as well as social, cultural, policy and cognitive factors (34). As shown in this study, the perceived school play environment may be one such important influence, being positively associated with children's recess PA behavior.

Apparently recess and lunchtime PA have different mediators and more research is needed to explore what these mediators are to be able to effectively change these behaviors.

Conclusion

The Transform-Us! intervention positively affected children's MVPA and LPA during recess but not lunchtime. There were no significant mediating effects on PA at recess or lunchtime. However, a positive perception of the school play environment was significantly related to girls' PA during recess. Researchers should explore mediating effects of PA interventions to assist in understanding how such interventions work and to improve ongoing and future interventions.

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Online Appendix 1. Mediated effects (axb) that were derived from single mediation analyses with asymmetric 95% CI using PRODCLIN.

	Recess MVPA axb (95%CI)	Recess LPA axb (95%CI)	Lunchtime MVPA axb (95%CI)	Lunchtime LPA axb (95%CI)
PA-I				
Social support from teachers	-0.024 (-0.07, 0.01)	-0.016 (-0.04, 0.00)	-0.016 (-0.06, 0.02)	0.002 (-0.02, 0.02)
Perceived availability of line markings	0.002 (-0.07, 0.08)	-0.013 (-0.10, 0.05)	-0.011 (-0.10, 0.05)	-0.011 (-0.08, 0.04)
Perceived accessibility of sports equipment	0.008 (-0.47, 0.52)	-0.000 (-0.15, 0.13)	0.012 (-0.56, 0.66)	-0.003 (-0.20, 0.15)
Perceived school environment	0.007 (-0.00, 0.02)	0.001 (-0.00, 0.01)	0.001 (-0.01, 0.01)	-0.001 (-0.01, 0.00)
- Boys	0.000 (-0.01, 0.02)	0.000 (-0.01, 0.01)	0.001 (-0.01, 0.02)	0.000 (-0.01, 0.01)
- Girls	0.032 (-0.00, 0.08)	0.008 (-0.00, 0.03)	0.013 (-0.00, 0.04)	-0.000 (-0.01, 0.01)
PA+SB-I				
Social support from teachers	-0.038 (-0.11, 0.01)	**-0.025***(-0.06, -0.00)	-0.025 (-0.09, 0.02)	-0.003 (-0.03, 0.02)
Perceived availability of line markings	-0.002 (-0.08, 0.07)	0.013 (-0.06, 0.09)	0.011 (-0.06, 0.09)	0.011 (-0.05, 0.07)
Perceived accessibility of sports equipment	-0.074 (-0.55, 0.27)	0.002 (-0.13, 0.13)	-0.107 (-0.36, 0.34)	0.025 (-0.11, 0.18)
Perceived school environment	0.006 (-0.00, 0.02)	0.001 (-0.00, 0.01)	0.001 (-0.01, 0.01)	-0.001 (-0.00, 0.00)
SB-I				
Social support from teachers	- 0.013 (-0.05, 0.01)	-0.009 (-0.03, 0.00)	-0.009 (-0.04, 0.01)	-0.001 (-0.01, 0.01)
Perceived availability of line markings	-0.000 (-0.07, 0.07)	0.002 (-0.07, 0.07)	0.002 (-0.07, 0.07)	0.002 (-0.06, 0.06)
Perceived accessibility of sports equipment	-0.164 (-0.74, 0.26)	0.006 (-0.18, 0.18)	-0.237 (-0.89, 0.22)	0.055 (-0.18, 0.25)
Perceived school environment	-0.008 (-0.03, 0.01)	-0.001 (-0.01, 0.00)	-0.001 (-0.01, 0.01)	0.001 (-0.00, 0.01)
- Boys	0.009 (-0.08, 0.11)	0.001 (-0.06, 0.06)	0.037 (-0.05, 0.14)	0.009 (-0.03, 0.05)
- Girls	0.044 (-0.00, 0.11)	0.011 (-0.00, 0.04)	0.019 (-0.00, 0.06)	-0.000 (-0.02, 0.02)

PA-I: Physical activity group; SB-I: Sedentary behavior group; PA+SB-I: Physical activity and sedentary behavior combined group,
MVPA=moderato-to-vigorous physical activity, LPA=light physical activity, 95%CI= 95% Confidence interval
All models adjusted for sex, maximum temperature at baseline and mid-intervention, baseline BMI, school cluster effect, intervention groups and baseline values of the outcome and the mediator variable
*p<0.05