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Environmental characteristics of early childhood education and care, daily movement behaviours and adiposity in toddlers: A multilevel mediation analysis from the GET UP! Study

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Abstract

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Environmental characteristics of early childhood education and care, daily movement behaviours and adiposity in toddlers: a multilevel mediation analysis from the GET UP! Study.

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Methods: 274 children (average age 19.73 ± 4.15 months) from 27 ECEC centres participated in this study. Environmental characteristics of ECEC centres were rated using the Infant/Toddler Environment Rating Scale-revised edition (ITERS-R). Daily movement behaviours were assessed using 24-hour accelerometry. Body mass index z-scores were used to indicate adiposity.

Results: There were no significant direct effects or indirect effects of environmental characteristics on toddlers' adiposity through daily movement behaviours. However, the environmental characteristics of "personal care routine" ($B=0.72$, $p=0.041$) and "activity" ($B=0.87$, $p<0.050$) were positively associated with the percentage of time these toddlers spent in moderate-to-vigorous physical activity (MVPA). "Listening and talking" was also positively associated with nap(s) durations ($B=4.08$, $p=0.001$).

Conclusion: The relationships between environmental characteristics of ECEC centres and adiposity in toddlers, as well as, the mediating roles of daily movement behaviours still need confirmation by future longitudinal and experimental studies with long follow-up periods. At the same time, a broader spectrum of environmental characteristics of these settings needs to be examined with toddlers' adiposity in future studies; other potential mediators may also need to be taken into considerations.

Keywords: childcare; physical activity; sedentary time; nap; weight status

1.Introduction

The global prevalence of overweight and obesity, in children under the age of 5, increased from 4.2% to 6.1% between 1990 and 2010, and is expected to reach 9.1% by 2020.¹ This is of concern as overweight and obesity at these ages may have detrimental health effects throughout life, as it is known that higher levels of adiposity in the early years track into later childhood² and adolescence.³ Moreover, rapid weight gain in the first 2 years of life has been associated with an increased risk of adult overweight.⁴ Therefore, there is a need to prevent and to address overweight and obesity in young children. To do this, a better understanding of the factors that associated with early childhood adiposity is needed.

The environment plays an important role in the development of childhood overweight and obesity.⁵⁻⁷ Young children are especially susceptible to environmental cues that promote obesity-related behaviours, because they may not be well prepared to make informed decisions to maintain a healthy weight status.⁸⁻¹⁰ Given the high attendance rate of young children in formal early childhood education and care (ECEC) centres in several countries,¹¹⁻¹³ many young children are exposed to these environments for most the day, which may have substantial influence on their weight status.¹⁴ Indeed, a recent systematic review identified 22 environmental characteristics of ECECs that have previously been examined in associations with young children's weight status,¹⁵ and concluded that those relationships were likely to be mediated by energy balance-related behaviours, such as physical activity and dietary intake.^{15,16} For example, "active time in ECEC centres", one of the environmental correlates identified in that review, is likely to influence children's weight status through an indirect effect on children's active levels, while "high sugar and high fat served in ECEC centres" may

be associated with children's food choice and energy intake, which, in turn, could affect their adiposity.¹⁵ However, the indirect effects of the ECEC environmental characteristics on young children's weight status through these behaviours has not yet been examined.¹⁵ An understanding of their mediating roles could help improve efficiency and effectiveness of environmental interventions in ECEC centres, as most of the interventions published so far were designed to prevent and to address early childhood overweight and obesity through changing intermediate behaviours.¹⁷

From a movement perspective, physical activity, sedentary time and sleep can be considered a continuum ranging from high to low/no movement, with the daily time allocation of these behaviours constituting a 24-h period.^{18,19} Since each of these movement behaviours as well as their combination have been associated with several health and developmental outcomes, including adiposity,²⁰⁻²³ Australia and Canada have recently published 24-h movement guidelines for the early years, to promote optimal health and development for young children.^{24,25} As attending ECEC programs usually contributed to a large proportion of daily time for toddlers (up to 11 hours), the environments in these settings are likely to influence young children's daily movement behaviours. For example, evidence suggests that ECEC environment may explain up to 50% of the children's daily variations in physical activity,²⁶⁻²⁹ and that several environmental characteristics of these settings (e.g. provision of active opportunities and the presence of outdoor environments) seems to be associated with children's physical activity and sedentary time.³⁰ However, although these two movement behaviours were common intermediate behaviours in most obesity prevention environmental interventions in ECEC centres,¹⁷ the indirect effects of the

environment characteristics on adiposity through physical activity and sedentary time are not fully understood yet.

On the other hand, daytime napping is an essential part of total sleep in early childhood, particularly during the first 3 years of life;³¹ and, nap time is part of the daily routine in most ECEC centres.³² Indeed, napping duration is more likely to be influenced by environmental settings, rather than by genetic predisposition.^{31,33,34} For example, in a Canadian birth cohort study with 995 twins, environmental influences explained a large proportion of variance in the participants' napping duration once they became toddlers - 33%, 48% and 79% for 18, 30 and 48 months olds, respectively.³¹ Nonetheless, young children's nap(s) pattern, duration and quality, as well as environmental influences of ECEC centres on nap(s) remain unclear.³⁵⁻³⁷ Since napping may also play a mediating role in the relationships between environmental characteristics of ECEC centres and adiposity in young children,¹⁵ it is important to examine the indirect effect of the environmental characteristics on adiposity through this daily movement behaviour.

Previous studies examining ECEC centre's environments and nap(s) duration in young children have used subjective measures (e.g. proxy-report),^{15,36} to assess napping, which are less accurate than objective measures and may affect the strength of the evidence.³⁸ Also, there is limited research in this area focus on children under the age of 3.^{15,39}

The aim of the present study was to examine the indirect effects of environmental characteristics on toddlers' adiposity through physical activity, sedentary time and

nap in a sample of Australian toddlers, using objective measures of ECEC centres' environments and daily movement behaviours. We hypothesized that there are indirect effects of environmental characteristics on toddlers' adiposity through physical activity, sedentary time and nap.

2.Methods

2.1 Participants and ECEC centres

The present study reported on a cross-sectional analysis of the baseline data from the *GET UP!* Study, described in full elsewhere⁴⁰, is a 12-month cluster randomized controlled trial (RCT) examining the effects of reducing sitting time on cognitive development and executive functions in Australian toddlers. Thirty ECEC centres from Illawarra region in NSW with children from a low- to medium socioeconomic background⁴¹ were recruited. All children aged 12- to 26 months at baseline without any diagnosed medical or psychological impairment were eligible to participate if they attended the ECEC services full-time (i.e. >6 h/day) at least two days per week. Our sample included 335 toddlers aged 19.8 ± 4.08 months, of which, 284 had valid accelerometer data (i.e., at least one 24-h period). Three ECEC centres (including 10 children with valid accelerometer data) dropped out from the study before the environmental assessment were conducted. Therefore, 274 participants from the remaining 27 ECEC centres had complete data and were included in the current analyses. Children who were excluded from the analyses were not significantly different from those included on demographic characteristics (age, sex and socioeconomic status). The University of Wollongong's Human Research Ethics Committee approved the study protocol (HE15/236) and the study was registered in

the Australian and New Zealand Clinical Trials Registry (ACTRN12616000471482, 11/04/ 2016, retrospectively registered).

2.2 Measures

Outcome

Adiposity

Body weight and height were measured according to standard procedures.⁴⁰ body height was measured to the nearest 0.1 cm in bare or stocking feet with the child standing upright against a portable stadiometer (Seca 254 Hamburg, Germany). Body weight was measured to the nearest 0.10 kg, lightly dressed (and without diapers) using a portable electronic weight scale (Seca 254 Hamburg, Germany).^{40,42,43} Body mass index (BMI) was calculated as $\text{weight(kg)}/\text{height(m)}^2$ and then BMI z-scores were then calculated by age and sex. Weight status (normal weight/overweight or obese) was determined according to the World Health Organization age and sex specific criteria.⁴⁴

Independent variables

Environmental rating of ECEC centres

The quality of the ECEC centre environment was objectively assessed using the Infant/Toddler Environment Rating Scale-revised edition (ITERS-R).⁴⁵ This instrument measures the environmental quality of ECEC centres for children from birth to 30 months of age, which has been widely used to assess overall or global quality of child care environment.⁴⁵⁻⁴⁷ The definition and measures of quality in ITERS-R draws from research evidence from relevant fields including health, development and education and considers professional views of best practice and the

practical constraints of real life in a ECEC setting. This 39-item instrument has a well-established validity and reliability.⁴⁵ For the full 39 items, the intraclass correlation was 0.92; overall the scale also has a high level of internal consistency with a Cronbach's alpha of 0.93.⁴⁵

The 39 items are distributed into seven subscales: (i) space and furnishings (e.g., indoor space; furniture for routine care and play; provision for relaxation and comfort); (ii) personal care routines (e.g., nap, diapering and toileting; health practices; safety practices); (iii) listening and talking (e.g., helping children understand language; helping children use language; using books); (iv) activities (e.g., fine motor; active physical play; art; music and movement; use of TV, video and/or computer); (v) interaction (e.g., supervision of play and learning; peer interaction; staff-child interaction); (vi) program structure (e.g., schedule; free play; group play activities); and (vii) parents and staff (e.g., provisions for parents; staff interaction and cooperation; staff continuity). Each item consists of several indicators and is rated on a 7-point scale: 1 (inadequate), 3 (minimal/adequate), 5 (good) and 7 (excellent). Scores for each item are aggregated to produce an average score for each subscale, and overall scores are computed for the full scale.⁴⁵

Following the ITERS-R manual and scoring protocol, all observers viewed a training video prior to the live observations. The scoring ratings were based on three and a half to four hours of observation followed by an interview with the educators to gather information regarding the indicators that the observers were not able to observe during the visit to the ECEC centre. All observations were double-coded, with two trained observers simultaneously rating the measure. In cases of disagreement, scores

were discussed between the two observers and reconciled scores were used in the data analysis.⁴⁵

Mediators

Physical activity, sedentary time and nap(s) were assessed using waist-worn accelerometers (Actigraph GT3X+), which have established validity and reliability in toddlers.⁴⁸ Participants were asked to wear the monitors 24-hrs for 7 consecutive days, except for water-based activities. During this period, parents and educators were also asked to log nap(s), nocturnal sleep and accelerometer non-wear time for each child. Accelerometer data were collected using a sampling rate of 30 Hz and re-integrated into 15-second epochs for analyses.⁴⁹

Nap(s)

In order to identify nap(s), accelerometry data were visually inspected minute by minute, with consideration of the activity logs. Specifically, the nap onset was initially located when a switch in the accelerometer output from the inclinometer sitting or standing to inclinometer lying or off was detected, which should roughly agree with the nap onset registered in the corresponding activity log. The onset was then identified as the first minute followed by at least 10 consecutive minutes with a vector magnitude of zero in the output. The nap offset was firstly located when a switch in the output from inclinometer lying or off to inclinometer sitting or standing was detected, which should roughly agree with the nap offset registered in the activity log. The offset was then identified as the first minute followed by at least 10 consecutive minutes with a vector magnitude > 0 in the output. Then, nap duration was calculated as the period between the onset time and the offset time. Similarly,

nocturnal sleep duration was identified with considering the nocturnal sleep registered in the activity logs.

Physical activity and sedentary time

After identification of nap(s) and nocturnal sleep, these periods were removed from the accelerometer data, which were then analysed by an automated data reduction program (ActiLife Software, Version 6.12.1 for Windows) to identify awake wear time (20 minutes of consecutive minutes of zero counts were flagged as non-wear awake time⁴⁹ and were also excluded from the analysis) as well as durations of physical activity and sedentary time. Levels of activity were classified using the following cut-points for toddlers⁴⁸: sedentary time (<25 counts/15 sec), light-intensity physical activity (25-420 counts/15 sec) and moderate-to-vigorous physical activity (MVPA) (>420 counts/15 sec). The percentages of awake wear time spent in each of these behaviours were then calculated.

Covariates

Child age and sex

Child age and sex were assessed by parental questionnaires.

Socio-economic status

Family socio-economic status of the children was assessed using postcode of residence and allocating from the corresponding value from the Australian Socio-Economic Indexes for Areas 2011(SEIFA-Index of Relative Socio-Economic Disadvantage).⁴¹ A low score on this index indicates a high proportion of relatively socio-economic disadvantaged people in an area (in terms of people's access to

material and social resources, and their ability to participate in society). Using the score, deciles ranging from 1 to 10 (higher decile indicates relatively less socio-economic disadvantages) are derived.⁴¹ For description purpose, participants were categorized in three groups: low socio-economic status (decile=1-3); middle socio-economic status (decile=4-6); and high socio-economic status (decile=7-10).

2.3 Statistical analysis

Descriptive statistics were presented as means and standard deviations.

A multilevel mediation analysis was conducted to examine the direct effects of independent variables (environmental rating of ECEC centres) on the outcome (BMI z scores), as well as, the indirect effects through potential mediators (percentage of awake time spent in light-intensity physical activity, MVPA, sedentary time, or nap(s) duration) in toddlers. Multilevel mediation analyses extend the classic mediation model (that assumes independent observations)^{50,51} to clustered data by using multilevel modelling.⁵²⁻⁵⁵ In the models, data collected at the lower level (e.g. children level) are called level-1 data, while data collected at a higher level (e.g. ECEC centre level) are called level-2 data.⁵²⁻⁵⁵ In the current study, a 2-1-1 model was employed, in which the first, second, and third numbers correspond to measurement levels of the independent (i.e. ECEC environmental rating – level 2 data), mediator (i.e. movement behaviours – level 1 data) and outcome (i.e. adiposity– level 1 data) variables, respectively (Figure 1).^{54,55}

Insert Figure 1 here

Level-1 covariates (i.e. age, gender and socio-economic status) were also included in the adjusted models. Parameters for the models, including fixed effects of independent variables and mediators as well as random effects of mediators (only random intercepts between mediators and the outcome were estimated⁵⁵), were estimated using restricted maximum likelihood estimation.⁵² Since the ECEC centre-level independent variables did not vary at the individual level, the within-group effects of independent variables were omitted.^{52,54} The mediation effects were therefore presented as between-group indirect effect⁵⁵ (i.e. the effect of the group differences in independent variables on the outcome through mediators).⁵²

The significance level was set at $p < 0.05$. The MLmed macro for SPSS (Version 24.0, IBM, USA) for the mediation models was used.^{52,53} This macro is available from: <https://njrockwood.com/mlmed/>.

3. Results

Table 1 presents the descriptive characteristics of the 274 participants (52.6% boys), with 23.7% being overweight or obese and 76.3% being normal weight. Participants were on average 19.73 ± 4.15 months old. Nearly half of their time at ECEC centres was spent being sedentary (47.2%).

Insert Table 1 here

The environmental rating scores of ECEC centres (N=27) are described in Table 2. Of the 7 environmental subscales, “program structure” was the one with the highest

average score (5.79 ± 1.26) whereas “personal care routine” the one with lowest average score (4.52 ± 1.27).

Insert Table 2 here

Results from unadjusted multilevel mediation analyses suggested that there were no direct effects of environmental rating scores on BMI z-scores; no indirect effects through the percentage of awake time spent in light physical activity, moderate-to-vigorous physical activity or sedentary time, or nap duration (Tables S1-4 & Figure S1-S4). Similarly, no significant direct or indirect effects of environmental rating scores on BMI z-scores were found in the adjusted models after controlling for age, sex and socio-economic status (Tables 3 to 6 & Figure S5-S8).

Insert Tables 3 to 6 here

The environmental rating subscales “personal care routine” ($B=0.72$, $p=0.041$) and “activities” ($B=0.87$, $p<0.050$) were positively associated with the percentage of awake time spent in moderate-to-vigorous physical activities, after controlling for age, gender and socio-economical status (Table 4). Also, the subscale “listening and talking” was strongly associated with nap duration after controlling for the same covariates ($B=4.08$ $p=0.001$) (Table 6). None of the daily movement behaviours were significantly associated with BMI z-scores.

4. Discussion

4.1 Overview of findings

In our study, there were neither significant direct effects of environmental characteristics on toddlers' adiposity nor indirect effects through the percentage of time they spent in physical activity or sedentary time or from their nap duration. However, the environmental characteristics of "personal care routine" and "activity" were positively associated with the percentage of time these toddlers spent in MVPA. At the same time, "listening and talking" was positively associated with nap(s) durations.

Neither direct nor indirect effects of environmental characteristics of ECEC centres on adiposity were significant in our study. Although previous studies have shown that environment may play a significant role in the development of overweight and obesity,^{8,56,57} it seems to manifest over a long time and, therefore, it may be difficult to be observed in children, younger than two years of age.⁵⁷ Indeed, in previous observational studies, the associations between environmental characteristics of ECEC centres and adiposity in young children were predominantly null.¹⁵ Moreover, interventions in ECEC centres with longer follow-up periods were more likely to detect changes both in intermediate behaviours as well as in adiposity, whereas those with shorter follow-up periods tended to only have effects on intermediated behaviours.¹⁷ In this light, the direct and indirect relationships between environmental characteristics of ECEC centres and adiposity in toddlers need to be further investigated through longitudinal and experimental studies with long follow-up designs. Secondly, there may be other environmental characteristics, rather than those examined in the present study, that may be associated with adiposity in young children. For example, there is no item on the ITERS-R scale assessing educators physical activity levels; however, it was evident in a study with 434 German children

aged 3 to 6 years that educators' habitual physical activity level was associated with these young children's weight status.⁵⁸ This association may be mediated by children's physical activity, that is, educators with higher levels of physical activity may promote children's physical activity,⁵⁹ which in turn could have a beneficial effect on children's adiposity.⁶⁰ Thus, it would be interesting if future studies consider a broader spectrum of environmental characteristics, in order to increase our understanding of how environmental influences of ECEC centres influence young children's adiposity and the mediating roles of daily movement behaviours. Lastly, indirect effects of environmental characteristics on adiposity may also be mediated through other potential variables, such as dietary intake, dietary behaviour and stress level. For example, previous studies have reported that children attending high-quality ECEC services had lower stress levels compared to those who attending lower quality ECEC services.^{61,62} In turn, an elevated cortisol level (a hormone sensitive to stress) responding to stress has been associated with obesity.⁶³ Therefore, inclusion of stress levels and other potential mediators in future mediation analyses may help to better understand how ECEC environments influence young children's adiposity.

None of the environmental characteristics examined in the present study were associated with light-intensity physical activity, whereas "personal care routine" and "activity" were positively associated with MVPA in our sample. ECEC centres with higher rating scores in the "activity" subscale were more likely to provide higher quality activities.⁴⁵ Since most of the activities observed (e.g. fine motor, gross motor, music and movement, dramatic play, sand and water play,⁴⁵ less use of screen devices) seem to encourage physical activity, children could be more likely to engage in MVPA when attending ECEC centres with higher "activity" ratings, compared

with those attending ECEC centres with lower ratings. Similarly, previous studies have found that the children attending ECEC centres, which provide greater active play opportunities, spent more time in physical activity.^{30,59,64,65} This provides guidance to help inform practice in ECEC; ECEC centres could increase physical activity levels in young children by improving the quality of active play activities.

Interestingly, ECEC centres with higher rating scores in the “personal care routines” subscale were associated with more MVPA in toddlers. These centres are more likely to provide higher standard and warmer care, and, specifically, to keep children healthy, hygienic and safe. We speculate that this might be related to children’s MVPA through psychological factors, such as feeling secure and safe, since greater psychological wellbeing has been associated with higher levels of physical activity in this age group.^{66,67} However, this speculation needs to be further confirmed by future studies.

The environmental rating scores for “listening and talking” was positively associated with toddlers’ nap duration. This subscale evaluates the way educators communicate with children, in terms of helping them understand and use language, as well as books use.⁴⁵ One possible explanation for its association with toddlers’ nap(s) duration may relate to their stress reactivity. Indeed, children tend to have a low level of cortisol in a high-quality ECEC centres,^{68,69} especially when they feel secure and comfortable being with educators.^{70,71} Since cortisol levels have been associated with nap duration,^{72,73} children attending ECECs with higher ratings in “listening and talking” may have a longer nap time because they feel less stressful. Alternatively, the relationship between “listening and talking” rating scores and toddlers nap duration

may be explained by their language development, since previous studies have reported that infants who napped tended to perform better in language learning than those who did not nap.^{74,75} If that is the case, nap(s) duration may play a moderating role in the relationships between language promoting environments in ECEC centres and language development in toddlers, although this speculation needs to be further confirmed by future studies.

None of the environmental characteristics examined was associated with sedentary time in toddlers. Indeed, few environmental characteristics of ECEC centres (i.e. outdoor environment, active opportunities and service quality) examined in previous studies have been associated with children's objectively measured sedentary time.³⁰ However, ECEC centres may encourage sedentariness as some children may spend up to 80% of their childcare day in sedentary activities.^{40,76} In order to reduce these sedentary time in young children, more studies are needed to identify other environmental characteristics of ECEC centres associated with their sedentary time.

4.2 Strengths and limitations

To the best of our knowledge, the present study is the first to examine the associations between environmental characteristics of ECEC centres and adiposity mediating through physical activity, sedentary time and nap, in toddlers. The use of an observational measure allowed the objective assessment of the quality of the ECEC centres' environment. Daily movement behaviours in young children were also measured objectively, with the use of accelerometers. These objective measures of the main variables of interest for this study should be considered its greatest strength, as they can be more accurate than subjective measures used in previous studies. Another

strength of the study is the use of multilevel mediation analysis, which allowed us to take into account the clustered nature of the data. However, this study is not without limitations. First, due to the cross-sectional design, causality of the relationships identified in this study cannot be inferred. Second, the sample is not representative which means the results are not generalizable. Lastly, due to the availability of data, some potential covariates, such as children's dietary behaviours or stress level, were not considered in the analysis.

5. Conclusion

Collectively, our hypothesis was not confirmed by our results. The environmental characteristics and overall quality of ECEC centres examined in the present study have neither direct effects on toddlers' adiposity nor indirect effects through daily movement behaviours, although these relationships need to be confirmed by future longitudinal and experimental studies with long follow-up periods. A broader spectrum of environmental characteristics of ECEC centres needs to be examined with toddlers' adiposity in future studies as well as these mediators. The mediating roles of other variables, such as stress levels or dietary intake and dietary behaviour, are also recommended to include in future studies.

The associations between the environmental characteristic of "activity" and toddlers MVPA indicates that, in practice, ECEC centres could promote a higher level of physical activity in young children by improving the quality of play activities and by providing more active opportunities. At the same, more studies are needed to understand the associations between "personal care routine" and MVPA, the

associations between “listening and talking” and nap, as well as other potential environmental characteristics associated with sedentary time, in young children.

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