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Potential Efficacy of the MOVERS Professional Development Programme: A Pilot Randomised Controlled Trial

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ABSTRACT

Background: High-quality early childhood education (ECE) environments positively impact child outcomes. This study examined the potential efficacy of a professional development (PD) programme on improving the quality of the ECE movement environment and children's physical activity, motor, literacy and numeracy skills.

Methods: A 6-month RCT involving 5 ECE services and 157 children (mean age 3.84 ± 0.61 years) was conducted. ECE services were randomly assigned to the intervention group ($n = 3$) or wait-list control group ($n = 2$). The PD comprised five monthly face-to-face sessions, including theory, practice and reflective thinking components. Outcomes included the quality of the ECE movement environment (MOVERS), children's gross motor skills (TGMD-2), physical activity (GT3X accelerometers), fine motor skills (ASQ-3), receptive vocabulary (PPVT-4) and numeracy (PENS). All outcomes were assessed at baseline and follow-up. Data were analysed using linear mixed models (SPSS, Version 26) and effect sizes were calculated. Educator engagement was collected using questionnaires.

Results: Large effect sizes were reported for the quality of the ECE movement environment ($d = 1.77–9.35$). Medium to large effect sizes were reported for children's gross motor skills ($d = 0.68–1.23$), and small to medium effect sizes were reported for three subscales of the numeracy test ($d = 0.43–0.63$). In the intervention group, a significantly greater number of children moved from being at risk of delay or delayed to normal development in fine motor skills (Phi = 0.21). Educators reported that the PD content was relevant and clearly explained, highlighting the hands-on components as the most valued aspect.

Conclusion: The MOVERS PD pilot programme resulted in changes in educators' pedagogy and practice and in children's gross and fine motor skills and numeracy skills. Future studies with larger sample sizes will be important to confirm these results.

1 | Introduction

Early childhood education (ECE) settings are an ideal setting for the promotion of movement and physical activity (Lum et al. 2022). Movement and physical activity in ECE settings are influenced by many factors, including class size, type and culture of setting, educator competence and confidence, educator qualifications and experience and the quality of the environment

Summary

- The quality of the early childhood education environment is important and directly relates to children's outcomes.
- Few studies have explored the importance of the movement environment in early childhood settings. Further, few early childhood policies highlight the importance of the movement environment for physical development.
- High-quality professional development can modify early childhood educators' pedagogy and practices.
- Further professional development opportunities that focus on the quality of the movement environment are needed.

(e.g., the movement environment) (Tonge et al. 2016, 2024). The movement environment relates to the environment that supports physical child development and includes components such as gross and fine motor development, movement, reflexes, sensors and physical activity. Recent studies have shown that a higher quality ECE movement environment is associated with more favourable physical activity and sedentary behaviour outcomes in children aged 3–5 years (Albertsen et al. 2023; Zhang et al. 2021).

ECE pedagogical quality can be enhanced through participation in professional development (PD) (Egert et al. 2018; Siraj et al. 2023). For example, Siraj et al. (2023) 1-year study (90 ECEs) showed that participation in a PD programme had a significant effect on ECE environmental quality and children's outcomes (including numeracy and literacy outcomes). However, to date, no known studies have explored the impact of a PD programme that focuses on improving the quality of the movement environment in ECE settings on physical activity and physical activity-related outcomes in children. The Movement Environment Rating Scale (MOVERS) PD programme, which is underpinned by Vygotsky's Sociocultural theory and the Zone of Proximal Development (Vygotsky 1978; Warford 2011), was developed to address this gap. The MOVERS PD programme is informed by components of the MOVERS environmental rating scale—a valid and reliable rating scale used to assess the quality of ECE movement environments (Archer and Siraj 2017). The MOVERS is a multifaceted scale that focuses on concepts related to movement, including fine and gross motor skills, resources and equipment. Additionally, it focuses on relational pedagogical aspects of quality relating to the movement environment, including movement vocabulary, observations and interactions and sustained shared thinking (i.e., ongoing and meaningful extended conversation).

The aim of this study was to examine the potential efficacy of an educator PD programme on the quality of the movement environment and children's (aged 3–5 years) physical activity and physical activity–related outcomes, including gross and fine motor skills and literacy and numeracy skills. Children's gross and fine motor skills and academic outcomes were included as there is evidence to suggest that these outcomes are associated with physical activity (e.g., Chou et al. 2022; Figueroa and An 2017). Additionally, other studies that have implemented PD programmes that focus on the quality of the ECE environment have reported changes in children's outcomes such as literacy and numeracy outcomes (Siraj et al. 2023); thus, exploration of these outcomes following implementation of the MOVERS PD programme was important.

2 | Methods

2.1 | Study Design

The MOVERS PD pilot programme was a cluster randomised controlled trial (RCT) and followed the CONSORT guidelines for pilot and feasibility trials (Eldridge et al. 2016).

This study was approved by the University of Wollongong Human Ethics Research Committee (2017/238) and was registered with the Australian New Zealand Clinical Trials Registry (ACTRN12624000694516).

2.2 | Setting and Recruitment

Five ECE centres, educators and children were recruited (December 2017/January 2018) (beginning of the school year). ECE directors and educators provided written consent to participate in the study, and parents provided written consent for their children to participate in the study. All centres were located within an hour from the main research facility, had an indoor and outdoor environment, enrolled a similar number of children and had the same National Quality Standard rating (i.e., national bench marking system used throughout Australia). Centres were randomised following baseline measurements (end of March 2018) to either the intervention or a wait-list control group. Follow-up assessments occurred at 6 months (October–November 2018).

2.3 | Participants

All educators, irrespective of their qualification (e.g., degree, diploma and certificate) were eligible to participate if they worked in rooms that catered for 3- to 5-year-old children. All educators from the intervention and control groups were female (range 20–+60 years). The number of degree qualified educators was similar in both the control and intervention groups (five educators from the control group were degree trained, and seven educators from the intervention group were degree trained). The average number of years of educator experience in the sector was also similar between the groups (12 years for the control group and 10 years for the intervention group). Children were eligible to participate if they were 3–5 years old at the start of the intervention and attended the ECE setting for at least 2 days a week. Those with a diagnosed condition that could affect their behaviour or mobility were excluded from the study. Table 1 highlights the demographics of the children and educators.

2.4 | Intervention

The intervention was a 6-month PD programme for educators. The PD included theory, practice and pedagogical reflective thinking components, delivered in two phases: Phase 1: a 1-day (7 h)

TABLE 1 | Characteristics of participants at baseline.

Baseline characteristics	Intervention (3 ECE services, children $n = 85$)	Control (2 ECE services children $n = 72$)	p
Age of children (years) (M, SD)	3.84 (0.57)	3.85 (0.64)	0.89
Sex of children (% male)	51 (60)	37 (51)	0.28
Number of days enrolled at ECE (M, SD)	3.13 (1.12)	3.06 (1.09)	0.68
ActiGraph wear time-valid days (≥ 180 min/day) (n, SD)	1.81 (1.27)	2.31 (1.51)	0.03*
Educator sex (% female)	15 (100)	11 (100)	

Abbreviations: ECE—early child education, M—mean, min—minutes, n—number, SD—standard deviation.
*$p < 0.05$.

face-to-face session (April 2018), which introduced educators to the research on quality in ECEs, the MOVERS and its key concepts, as well as discussion pertaining to specific areas for improvement. Phase 2 comprised half-day PD sessions (four monthly sessions, 3.5 h each, May–October 2018) and on-site mentoring sessions. During the half-day session, two to three items from the MOVERS were discussed in detail. Between PD sessions, educators were encouraged to reflect on their pedagogical practice and implement new pedagogies, which were discussed in the PD sessions. The mentoring sessions were dispersed between the half-day PD sessions. These acted as support mechanisms for educators as they made changes within their centres. During these sessions, educators had the opportunity to show the MOVERS PD in practice and discuss barriers and challenges considering their specific context. Table 2 summarises the content of the PD sessions.

This intervention study was guided by Vygotsky's sociocultural theory (Vygotsky 1978) and focused on the four stages of the Zone of Proximal Teacher Development: self-assistance, expert-assistance, internalisation and recurrence (Vygotsky 1978; Warford 2011). Educators were encouraged to reflect on their current knowledge, skills and experiences (self-assistance); critically reflect on current pedagogy and practice (teacher assistance); and then explore methods of application of their new knowledge and skills within their individual settings (Table S1).

2.5 | Wait-List Control Group

The wait-list control group continued their usual practice during the intervention stage and participated in the PD after follow-up. Usual practice involved children participating in inside and outside free play learning experiences. Minimal intentional physical activity learning experiences were offered. Usual equipment, such as climbing frames and balls, was available for the children to play with throughout the day.

2.6 | Outcomes

ECE centre outcomes and child outcomes were assessed at baseline and follow-up using valid and reliable instruments (Dunn and Dunn 2007; Squires et al. 2009; Ulrich 2000). All child outcomes were individually administered in the ECE settings, and scores for object control skills were compared with age- and sex-adjusted norms, and locomotor, fine motor skills and literacy outcomes were compared with age-adjusted norms. The remaining adjustments for sex and age were completed through the statistical analysis.

TABLE 2 | Overview of the MOVERS professional development programme.

Session	Length (h)	Content covered
1	7	Importance of the quality of the ECE for children's future outcomes; measuring quality of ECE environment; the importance of physical-movement domain on other domains of child development; providing resources; engaging in movement with children indoors and outdoors
2	3.5	Movement vocabulary; sustained shared thinking
3	3.5	A case for physical development/ physical activity; physical activity guidelines; supporting curiosity and problem-solving
4	3	Practical examples of activities that can be facilitated inside and outside which focus on gross and fine motor skills, physical activity inside and outside, integration with other curriculum areas, planning and movement vocabulary
5	2	Recap of the previous sessions; how the elements of the training relate to NQS and EYLF

Abbreviations: EYLF—Early Years Learning Framework, NQS—National Quality Standards.

2.7 | ECE Centre Outcomes

To assess the quality of the movement environment, the MOVERS (Archer and Siraj 2017) was used. The MOVERS

comprises 11 items divided into four subscales (Table 3). Each item is rated from 1 to 7, where 1 equals inadequate and 7 equals excellent quality. The average score for a subscale is the sum of the ratings of all its items divided by the number of items. The sum of ratings of all scale items divided by the total number of items gives a total mean score for the scale (11 items of MOVERS). The MOVERS has been shown to have good reliability (including test–retest reliability) and internal consistency (Kazmierska-Kowalewska et al. 2021). MOVERS ratings were collected through day-long observations and document reviews (e.g., centre policies, planning and records). The data collector positioned themselves in a nonobtrusive position within the ECEs and did not disrupt normal proceedings. Interactions between children, educators and the data collector were minimal. The MOVERS observation day also involved a 45-min discussion with an ECE staff member (centre director and/or room leader). The data collector was trained prior to data collection. The training involved a day-long theory session and several in-field practice ratings in ECE centres that were not involved in this study.

2.8 | Child Outcomes

ActiGraph GT3X accelerometers (ActiGraph Corporation; Pensacola, USA) were used to measure children's physical activity (Janssen et al. 2013). During waking hours at the ECE setting, children were asked to wear an accelerometer on the right hip, secured with an elastic belt. Centre hours were from 6:30 AM to 6:00 PM; however, accelerometer data were only collected from 9 AM to 3.00 PM, as this was when most of the children were present. The number of days the children wore the accelerometers was dependent on the number of days that the children attended the ECE (range 2–5 days). Data were integrated into 15-s epochs. Pate's modified cut points (SB ≤ 25 counts/15 s, LPA: 25–419 counts/15 s and MVPA ≥ 420 counts/15 s) were applied as these are the most accurate in preschool-aged children (Evenson et al. 2008; Pate et al. 2006). Nonwear time was defined as 20 min of consecutive zeros, and valid wear time was defined as a minimum of 1 day, with at least 3 h of recorded data during ECE centre hours (Stanley et al. 2016). The Actilife software was used to analyse accelerometer data (Version 6.13.4).

Children's gross motor skills were assessed using the Test of Gross Motor Development, second edition (TGMD-2) (Ulrich 2000). The skills were demonstrated to the children, and then, two test trials of each skill were videorecorded. Each skill was scored based on the three to five components. One point was given if the child performed the skill component correctly, and 0 points were given if the child did not perform the skill component correctly. The sum of the scores from the two trials was then averaged to give a raw score for each skill. Locomotor skills (e.g., run, hop and leap) were summed to provide a locomotor subset score, and the object control skills (e.g., roll, bounce and kick) were summed to provide an object control subset score. An overall standard score was also calculated (Ulrich 2000). Interrater reliability for the TGMD-2 scoring was assessed using the percentage of agreement, which ranged from 85% to 97.5%.

Children's fine motor skills were assessed using the Ages and Stages Questionnaire third edition (ASQ-3) (Squires et al. 2009). Six questions relating to fine motor skills were used in this study. The data collector answered 'yes' to indicate that the child performed the skills, 'sometimes' to indicate an occasional or emerging response from the child or 'not yet' to indicate that the child did not yet perform the skill. The responses were converted into point values ('yes'—10, 'sometimes'—5 and 'no'—0). Raw scores were assessed against age- and sex-adjusted norm values to assess if the child's results were below, within or above

TABLE 3 | Subscales and items from the MOVERS.

Subscale	Items
1. Curriculum, environment and resources for physical development	1. Arranging environmental space to promote physical activity 2. Providing resources including portable and/or fixed equipment 3. Gross motor skills 4. Body movement to support fine motors skills
2. Pedagogy for physical development	5. Staff engaging in movement with children indoors and outdoors 6. Observation and assessment of children's physical development indoors and outdoors 7. Planning for physical development indoors and outdoors
3. Supporting physical activity and critical thinking	8. Supporting and extending children's movement vocabulary 9. Encouraging sustained shared thinking by communicating and interacting through physical activity 10. Supporting children's curiosity and problem-solving indoors and outdoors
4. Parents/carers and staff	11. Staff inform families about children's physical development and the benefits to their learning, development and health

the developmental cut-off points (Squires et al. 2009). In this study, the 33-, 36-, 42-, 48-, 54- and 60-month ASQ-3 questionnaires were used according to the participant's age.

The Peabody Picture Vocabulary Test fourth edition (PPVT-4) was used to measure literacy—specifically receptive vocabulary (Dunn and Dunn 2007). The PPVT-4 contains 19 sets of 12 items, with gradually increasing difficulty. For each item, the data collector said a word, and the child responded by selecting one of four pictures that best illustrated the meaning of the word. This pattern continued until eight or more errors occurred within one set. One point was given for each correct answer. Following the assessment raw scores were transformed into standard scores and growth scale values (GSVs, which measure performance over time). Standard scores and GSV are converted from raw scores using relevant tables (Dunn and Dunn 2007).

The Preschool Early Numeracy Scale was used to assess numeracy skills (Purpura and Lonigan 2015). Eight of the tasks were used (one-to-one counting, counting subsets, subitising, set comparison, number order, numeral identification, set-to-numeral and verbal counting). Each task comprises several items. A child received one point for the correct response to each item and zero points for the wrong answer. The score for a task was the sum of the ratings of all its items, and the total numeracy score is the sum of all items of all tasks.

2.8.1 | Educator Engagement Questionnaires

Participants from the intervention centres completed a written evaluation questionnaire at the end of each face-to-face PD session and another final questionnaire at the end of the intervention. These questionnaires asked about their engagement with the content, strengths, weaknesses and quality of the PD programme and educators' confidence in implementing the PD content. Questionnaires consisted of 13–35 statements that were answered using a 5 point Likert scale and four to nine open-ended questions. Questions used in the questionnaires are included in Table S2. Educators from both the intervention and control groups also completed a questionnaire, which asked about their demographic details (age, sex, qualifications, years of experience: total years worked in the industry and time worked in the present centre) and their past PD experiences. Educators' attendance at each PD session was recorded.

2.9 | Statistical Analysis

Analyses were performed in SPSS (Version 26, IBM Corporation). Linear mixed models were used to analyse gross motor skill (TGMD-2), physical activity (accelerometers), literacy (PPVT-4) and numeracy (PENS). Fine motor skill scores (ASQ-3) results were presented as proportions, and chi-square was calculated. Standardised effect sizes (Cohen's d) were calculated to demonstrate effects and trends and are the focus of the results and discussion (Cohen 2013). Adjusted mean differences (the difference between the change in scores from baseline to follow-up between the intervention group and the control group), 95% confidence intervals, means, standard deviations and p values ($p < 0.05$) were also reported. Likert scale data from the educator engagement questionnaires were averaged. Qualitative data from the educator engagement questionnaires were analysed thematically (Braun and Clarke 2006).

3 | Results

The flow of participants is shown in Figure 1. Characteristics of participants at baseline are shown in Table 1. The number of valid days of wearing the ActiGraph at baseline was significantly higher for the control group.

3.1 | ECE Centre Outcomes

At baseline, the overall quality of the movement environment and pedagogy was similar for both groups ($p < 0.05$) (Table 4). At the end of the intervention, large effect sizes were reported for Subscales 1–3 and the overall MOVERS score (Table 4).

3.1.1 | Child Outcomes

Large effect sizes were reported for gross motor skills, and small to medium effect sizes were reported for three of the 12 numeracy tasks (Table 5A). A significantly greater number of children moved from being at risk of delay or delayed to normal development in fine motor skills in the intervention group (Table 5B).

3.1.2 | Educator Engagement Questionnaire

The intervention group comprised 14 educators out of a possible 15. Thirteen educators participated in the first two PD sessions, 10 educators participated in the third session and nine participated in the fourth and fifth PD sessions. Seven educators participated in all five sessions. Educators who did not attend the PD sessions had conflicting schedules when the PD was planned. Overall, based on the answers from the questionnaires, educators thought that the PD content was relevant and clearly explained, and educators perceived that they felt empowered to make changes in their pedagogy and practice following the PD (Table 6). Educators rated the length of the PD the lowest; educators suggested that some of the sessions were too long and that they found it difficult to make time for all the PD sessions (Table 6).

Ten out of 14 educators completed the postintervention questionnaire. In general, educators suggested their pedagogy and practice had changed as a result of the PD. Educators were most favourable about the hands-on components of the PD; they suggested that the hands-on components inspired them to think creatively and try new approaches to physical activity learning experiences in their daily routines. Additionally, other educators mentioned that they also liked the research-based PD and the opportunity to reflect on their current practices. Educators suggested that the main challenge to ongoing implementation was providing physical activity learning experiences both inside and outside—providing opportunities indoors for physical activity was a key message in the PD.

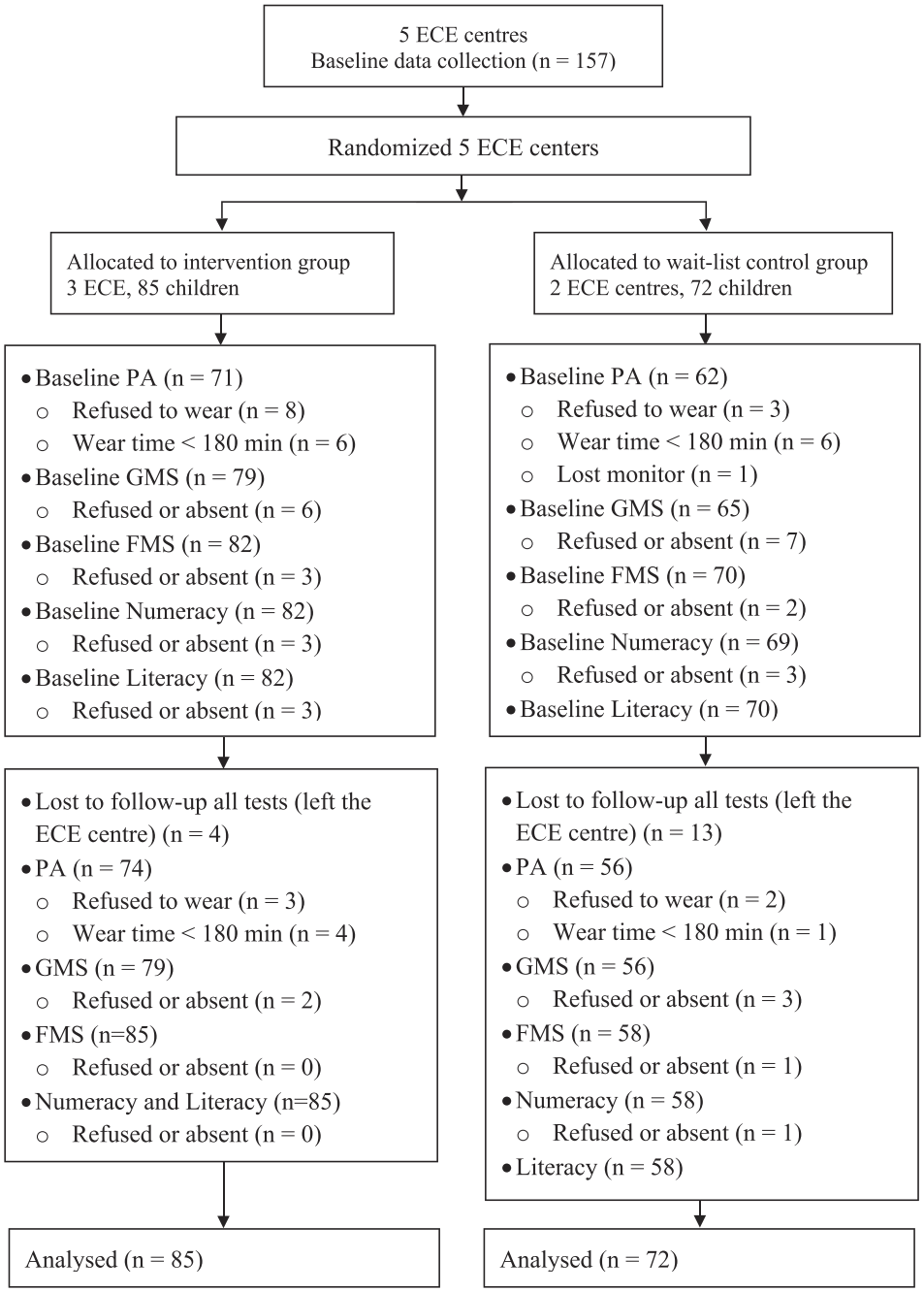

FIGURE 1 | Flow of participants through the MOVERS pilot PD programme. FMS—fine motor skills, GMS—gross motor skills, PA—physical activity.

4 | Discussion

This study assessed the potential efficacy of a PD programme on the pedagogical quality of the movement environment and children's outcomes. Large effect sizes were reported for Subscales 1–3 and the overall MOVERS score. Previous work using the MOVERS highlighted specific items from the MOVERS that are rated lower; for example, Item 2, 5 and 9. Although the PD broadly focused on the importance of physical development and physical activity in ECE settings, many of the practical hands-on examples related to Items 2, 5, 8 and 9. For example, Item 5 focuses on physical activity opportunities indoors and outdoors. Throughout the PD, educators were encouraged to participate in several examples of indoor physical activity learning experiences that utilised a variety of portable resources and equipment. Similarly, the focus of Item 9 is sustained shared thinking (an approach that focuses on ongoing and meaningful conversation which extend and explore children's thoughts and ideas examples) and throughout the PD educators were encouraged to practice this approach and think about situations within their own context where sustained shared thinking could be implemented. Our data suggest educators changed their pedagogy and practice because of the PD and implemented some key changes that resulted in increased quality. These results are consistent with other studies that have reported positive and meaningful changes

TABLE 4 | Changes in the quality of the movement environment (MOVERS) following the MOVERS professional development programme.

	Control baseline Mean (SD)	Control follow-up Mean (SD)	Intervention baseline Mean (SD)	Intervention follow-up Mean (SD)	Adjusted mean difference (95% CI)	*p*	Effect size
Subscale 1	2.75 (0.35)	2.88 (0.53)	2.67 (0.29)	4.75 (0.66)	1.96 (0.26, 3.65)	0.03*	2.70
Subscale 2	2.17 (0.24)	2.33 (0.00)	2.56 (0.19)	4.67 (0.00)	1.94 (1.34, 2.55)	< 0.01*	9.35
Subscale 3	1.00 (0.00)	1.17 (0.24)	1.67 (0.33)	3.22 (0.19)	1.39 (0.61, 2.17)	0.01*	3.18
Subscale 4	3.00 (0.00)	3.00 (0.00)	3.00 (0.00)	4.67 (1.15)	1.67 (−1.07, 4.41)	0.15	1.77
Total score	2.14 (0.06)	2.27 (0.26)	2.39 (0.21)	4.30 (0.28)	1.77 (1.02, 2.52)	< 0.01*	4.34

Note: Subscale 1: Curriculum, environment and resources for physical development. Subscale 2: Pedagogy for physical development. Subscale 3: Supporting physical activity and critical thinking. Subscale 4: Parents/carers and staff. The adjusted mean difference was the difference between the change in scores from baseline to follow-up between the intervention group and the control group.
Abbreviation: SD—standard deviation.
*$p < 0.05$.

in the quality of the ECE environment following educator PD (Egert et al. 2018; Siraj et al. 2023; Wilcox-Herzog et al. 2013). However, this is the first study to show that the quality of the movement environment can be enhanced through targeted PD. Given the size of this study (i.e., a pilot study) further larger scale studies would be beneficial to support these findings.

In this study, medium to large effect sizes were reported for locomotor skills, object control skills and the total gross motor score. It is difficult to compare these results to other ECE physical activity interventions (e.g., Ali et al. 2021; Lindsay et al. 2020; Wick et al. 2017) as few previous studies reported effect sizes. In studies where effect sizes have been reported, for example, in Jones et al. (2016) ($d = 0.09–0.58$) and Jones et al. (2011) ($d = 0.01–0.75$), the effect sizes in this study are much larger ($d = 0.68–1.17$). The large effect sizes in this study are perhaps surprising, given that gross motor skills need to be taught through instructions and practice (Gallahue and Ozmun 2006). In contrast to this study, studies facilitated by Jones et al. (2016) and Jones et al. (2011) both involved specific gross motor instruction. The targeted components of the PD content may have contributed to the changes in gross motor skills reported in this study.

Small to medium effect sizes were reported for three of the 12 numeracy tasks, and a significantly greater number of children moved from being at risk of delay or delayed to normal development in fine motor skills in the intervention group (effect sizes could not be determined for fine motor skills). To date, only two studies have explored the impact of ECE physical activity interventions on child-related numeracy outcomes, and no studies have explored the impact of physical activity intervention on child-related fine motor outcomes. Several studies have explored changes in physical literacy outcomes following the implementation of an ECE-based physical activity intervention, but none have explored literacy-specific outcomes (e.g., Buckler et al. 2023). Capio et al. (2024) recently evaluated a co-designed motor-math intervention implemented in ECE settings. Significant changes between the intervention group and control group were reported for gross motor skills and physical activity; no changes were reported for mathematics skills. Cohrssen and Niklas (2019) evaluated a single-group pretest–post-test study incorporating play-based maths games. Significant changes in numeracy outcomes were reported for the intervention group compared to the control group. However, neither of these studies reported effect sizes; thus, further comparison with the current study is difficult.

Although the MOVERS PD did not specifically focus on gross motor skills, fine motor skills or numeracy outcomes per se, throughout the PD educators were encouraged to reflect on their own pedagogical practices regarding the provision of gross and fine motor skills and the integration of physical activity and other curricula areas. Specifically, educators reflected on where (indoor/outdoor environment) and what gross and fine motor skill opportunities were provided in their setting and how physical activity learning opportunities were incorporated into other curriculum areas. These reflections were complemented with in-depth discussion pertaining to the role of educators (i.e., role modelling and engagement) during these learning experiences and participation in practical hands-on examples. Collectively, the intentional critical reflection, in-depth discussions and the practical, applicable activities may have contributed to the change in gross motor skills, fine motor skills and numeracy-related outcomes.

In contrast to other physical activity ECE interventions (Lum et al. 2022), this study found a null effect on device-measured physical activity. It is difficult to explain why changes in gross motor skills were detected but not physical activity. It is plausible to suggest that if children were participating in more gross motor activities that this would correlate with more physical activity. One possible suggestion for the null physical activity results could be that the content of the PD was too broad and in turn the emphasis on providing opportunities for intentional physical activity may have been too subtle. Several studies have shown that modifying children's physical activity in ECE setting is achievable (Finch et al. 2016; Jones et al. 2019; Lum et al. 2022; Peden et al. 2018); however, in all previous studies, the focus has been specifically on increasing opportunities for physical activity (i.e., providing additional adult-led structured time for physical activity or providing additional session outside for physical activity). Further instruction for educators may have been needed to increase the time spent in physical activity in this study.

TABLE 5A | Changes in children's gross motor skills, physical activity, numeracy and literacy following participation in the MOVERS professional development programme.

	Control baseline Mean (SD)	Control follow-up Mean (SD)	Intervention baseline Mean (SD)	Intervention follow-up Mean (SD)	Adjusted mean difference (95% CI)	*p*	Effect size (Cohen's *d*)
Gross motor skills							
Object control standard score (1–20)	6.35 (1.43)	5.98 (1.60)	6.01 (1.40)	6.75 (1.57)	1.18 (0.46, 1.90)	<0.01*	0.68
Locomotor standard score (1–20)	6.48 (1.63)	6.85 (1.61)	6.49 (1.83)	8.95 (1.67)	2.08 (1.27, 2.89)	<0.01*	1.17
Sum of standard scores (2–40)	12.83 (2.54)	12.83 (2.52)	12.51 (2.70)	15.69 (2.42)	3.28 (2.05, 4.51)	<0.01*	1.23
Physical activity							
Sedentary (min/h)	41.55 (4.41)	40.09 (4.59)	43.71 (5.89)	42.02 (5.45)	0.39 (−2.10, 2.88)	0.76	0.08
Light intensity (min/h)	9.06 (1.44)	9.49 (1.78)	8.20 (2.10)	8.69 (2.03)	−0.30 (−1.21, 0.62)	0.52	−0.17
Moderate intensity (min/h)	6.99 (2.24)	7.65 (2.29)	5.96 (2.76)	6.80 (2.69)	−0.04 (−1.25, 1.16)	0.94	−0.02
Vigorous intensity (min/h)	2.40 (1.30)	2.77 (1.33)	2.13 (1.70)	2.49 (1.39)	−0.05 (−0.75, 0.65)	0.90	−0.03
Light to vigorous intensity (min/h)	18.45 (4.41)	19.91 (4.59)	16.29 (5.89)	17.98 (5.45)	−0.39 (−2.88, 2.10)	0.76	−0.08
Numeracy							
One-to-one counting cardinality (0–8)	3.53 (2.72)	5.61 (2.05)	3.90 (2.37)	6.35 (1.97)	0.21 (−0.84, 1.26)	0.70	0.12
Counting a subset (0–10)	2.60 (2.88)	4.26 (3.20)	2.79 (2.65)	5.90 (2.89)	1.14 (−0.19, 2.46)	0.09	0.54
Subitising (0–7)	2.53 (1.67)	3.47 (1.24)	2.68 (1.41)	4.13 (1.14)	0.50 (−0.13, 1.13)	0.12	0.38
Set comparison (0–6)	3.32 (2.11)	4.12 (1.97)	3.83 (1.88)	5.54 (0.86)	0.82 (0.02, 1.61)	0.04*	0.43
Number order (0–6)	1.37 (1.68)	2.58 (2.07)	1.21 (1.72)	3.53 (1.86)	0.88 (0.03, 1.73)	0.04*	0.54
Numeral identification (0–9)	3.65 (3.14)	5.35 (2.67)	3.33 (2.90)	5.64 (2.81)	0.31 (−1.02, 1.64)	0.65	0.16
Set to numerals (0–5)	1.98 (1.56)	2.44 (1.89)	1.99 (1.53)	3.58 (1.54)	0.96 (0.21, 1.70)	0.01*	0.63
Verbal counting (0–7)	2.09 (1.35)	3.49 (2.73)	2.12 (1.32)	3.62 (1.77)	−0.10 (−0.96, 0.76)	0.83	−0.05
Total numeracy score (0–58)	21.05 (14.76)	31.33 (14.18)	21.85 (12.85)	38.27 (12.64)	4.70 (−1.52, 10.91)	0.14	0.56
Literacy							
PPVT-4 Standard score (20–160)	90.91 (17.69)	100.11 (15.75)	99.59 (14.08)	109.59 (12.39)	−0.04 (−6.78, 6.70)	0.99	0.00
PPVT-4 GSV (15–270)	101.95 (21.78)	121.26 (18.06)	110.72 (16.31)	131.86 (13.31)	0.50 (−7.41, 8.40)	0.90	0.05

Abbreviations: GSV—growth scale value, min/h—minutes per hour, *n*—number, SD—standard deviation.
*$p < 0.05$.

TABLE 5B | Changes in children's fine motor skills following the MOVERS professional development programme.

	Control		Intervention				
	ASQ-3 (0 and 1)	ASQ-3 (2)	ASQ-3 (0 AND 1)	ASQ-3 (2)	Pearson chi-square	Phi	*p*
BL (*n*)	17	40	18	60	0.38	0.08	0.38
BL (%)	29.8	70.2	23.1	76.9			
FUP (*n*)	16	41	9	69	0.01	0.21	0.01*
FUP (%)	28.1	71.9	11.5	88.5			

Note: 0 = delayed fine motor skills, 1 = at risk of delay in fine motor skills, 2 = normal development in fine motor skills.
Abbreviations: ASQ-3—Ages and Stages Questionnaire third edition, BL—baseline, FUP—follow-up.
*$p < 0.05$.

TABLE 6 | Educator engagement questionnaire for the MOVERS professional development programme sessions.

	Session 1	Session 2	Session 3	Session 4	Session 5
					Postintervention questionnaire
	n = 12	*n* = 13	*n* = 8	*n* = 9	*n* = 10
Content was relevant[a]	4.92	4.15	4.38	4.67	4.5
Content was clearly explained[a]	4.58	4.46	4.63	—	4.6
Hands-on components were appropriate[a]	4.67	4.38	4.00	4.56	4.8
It was clear what I needed to do[a]	4.58	4.46	4.13	—	4.5
I was empowered to make change[a]	4.58	4.38	4.13	4.56	4.6
Length was appropriate[a]	4.00	4.00	3.13	4.00	3.2

[a]The 5-point Likert scale: (1) *strongly disagree*; (2) *disagree*; (3) *neither agree nor disagree*; (4) *agree*; (5) *strongly agree*.

It is well established that high-quality, evidence-based PD is impactful in changing ECE educators' pedagogy and practice (Egert et al. 2018; Siraj et al. 2023; Wilcox-Herzog et al. 2013). Current evidence from the ECE sector, suggests that PD is most effective when it is ongoing in nature and engages at least two educators from a specific ECE setting (Egert et al. 2018; Siraj et al. 2019). Prolonged PD allows for 'think time' and 'soak time' whereby educators have the capacity to reflect on current pedagogy and practices and then plan for change. It also allows time for educators to trial new practices and modify them to suit their setting. The participation of several educators from the same ECE setting in the PD reduces the need for knowledge transfer, which is often diluted from one educator to another. Furthermore, it provides a support structure for educators as they modify their practices. Despite these best practice principles, educators in this study suggested the length (number and amount) of the PD sessions was a challenge. Ongoing discussion is needed with the ECE sector to think about the effective and sustainable models of PD; such models might include hybrid (online and face to face) and on-site PD (Peden et al. 2018).

The strengths of this study include the gold standard cluster RCT design, the use of valid and reliable data collection instruments and the inclusion of ECE centre outcome data and children's outcome data. However, the results should be interpreted with caution, considering the small sample size (Cliff et al. 2009). Although small, effect sizes were calculated for most outcomes, which meant that the data could be compared with other studies. Additionally, other factors that may have influenced the quality of the environment were not explored in this study. Factors such as educators' qualifications (i.e., degree, diploma or certificate), beliefs, experiences and opportunities for PD participation and educators' engagement with national curriculum documents were not considered in the analyses. These are important factors to consider, as it is well known that, for example, educator's qualifications directly influence the education that is provided in ECE settings, with higher qualified educators providing more comprehensive education than those who have completed lower qualifications (Manning et al. 2017).

This is one of the first known studies to explore the impact of a PD intervention on the quality of the movement environment, children's physical activity and children's physical activity-related outcomes. Small to large effect sizes pertaining to the quality of the movement environment, gross motor skills and numeracy outcomes were reported. These are encouraging results; however, larger studies will be needed to confirm these findings. Additionally, studies that explore associations/mediation factors between the quality of the movement environment and children's outcomes would be beneficial.

Author Contributions

Kalina M. Kazmierska-Kowalewska: conceptualization, investigation, writing – original draft, methodology, writing – review and editing,

formal analysis, data curation. **Anthony D. Okely:** conceptualization, investigation, methodology, writing – review and editing, supervision. **Iram Siraj:** conceptualization, writing – review and editing, supervision. **Carol Archer:** writing – review and editing, conceptualization. **Sanne L. C. Veldman:** conceptualization, writing – review and editing, formal analysis. **Rachel A. Jones:** conceptualization, writing – original draft, methodology, writing – review and editing, supervision.

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Ethics Statement

This study was approved by the University of Wollongong Human Ethics Research Committee (2017/238) and was registered with the Australian New Zealand Clinical Trials Registry (ACTRN12624000694516).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1.** Connections between Zone of Proximal Development and the MOVERS pilot professional development programme. **Table S2.** Example of questions used to assess educator engagement of the MOVERS professional development programme.