Early Childhood Education Journal (2023) 51:801–810
https://doi.org/10.1007/s10643-022-01336-z

Validity and Reliability of a Fine Motor Assessment for Preschool Children

Karel F. B. Strooband[1] · Steven J. Howard[1,2] · Anthony D. Okely[1,2] · Cathrine Neilsen-Hewett[1] · Marc de Rosnay[1]

Accepted: 9 March 2022 / Published online: 25 March 2022

Abstract

Due to the lack of tools that can be easily used by practitioners, there is a need to develop acceptable embedded ways to assess children's fine motor skill development within early childhood education and care settings. This study examined the validity and reliability of a brief and ecologically valid fine motor assessment tool for preschool-aged children; the fine motor growth assessment (i.e., FINGA). Children's fine motor performance on FINGA was compared with widely-used and validated performance-based (Peabody Developmental Motor Scales 2nd edition) and informant-based (Ages and Stages Questionnaire 3rd edition) fine motor assessments. Ninety-one children [mean age (y) ± SD = 4.50y ± 0.68] were assessed within seven early childhood education and care services in New South Wales, Australia. Exploratory factor analyses (EFA) and linear regression analyses showed that FINGA had good internal consistency (EFA of 73%) and age sensitivity ($B_{std} = 0.69$, $p < 0.001$), and bivariate correlation analyses demonstrated good concurrent validity (*r*s from 0.69 to 0.84, *p*s < 0.001) against the two comparison assessments. Because of its brevity and ecological validity, the FINGA tool should be further examined as a routine fine motor skills assessment administered within the context of universal early childhood education and care service provision.

Keywords Fine motor skills · Assessment · Preschoolers · Early childhood development

Introduction

From an early age, fine motor skills are necessary for many everyday activities (e.g., getting dressed, eating, crafts, etc.) and for successful engagement in early learning experiences that young children are presented. Fine motor skills consist of actions that require the use of hand or finger movements, along with visual perception integration that allows hand–eye coordination to ensure appropriate physical responses (Luo et al., 2007). Within preschool and primary school settings, daily routines and activities inherently involve opportunities for children to engage in and practice fine motor skills (Caramia et al., 2020; Marr et al., 2003). Several studies estimate that between 10 and 24 percent of pre-school-aged children have fine motor skill deficits (Bello et al., 2013; Handel et al., 2007; Troude et al., 2011). Despite this high rate of early fine motor difficulty, there is consistent evidence that interventions delivered through preschool settings can produce meaningful benefits for children (Strooband et al., 2020a, 2020b). The high prevalence of fine motor delay together with evidence of such efficacious interventions indicates a need for increased awareness and early identification, so that adequate support can be provided within the context of young children's ongoing daily activities.

A systematic review of motor skill interventions and fine motor development in young children found that, despite variation in programs and approaches, most intervention programs were successful in promoting fine motor skills (Strooband et al., 2020a, 2020b). Importantly, most of these interventions were implemented in preschool settings and led by early childhood educators. These findings strongly support the feasibility of bringing about wide-spread improvements in young children's fine motor skill development through educator practices embedded in universal preschool programs. Given that approximately half of all

✉ Karel F. B. Strooband
karels@uow.edu.au

[1] Early Start, Faculty of Arts, Social Sciences and Humanities, University of Wollongong, Wollongong, Australia

[2] Illawarra Health and Medical Research Institute, Faculty of Science Medicine and Health, University of Wollongong, Wollongong, Australia

children world-wide are enrolled in early childhood education services before age 5 (OECD, 2016), there is great potential to positively impact young children's development.

For motor skill interventions to be most effective, however, fine and gross motor experiences need to be tailored to children's needs and target skills known to be predictive of later development (Strooband et al., 2020a, 2020b). Tailoring experiences requires accurate assessment and differentiation of children based on ability, which has traditionally depended on the administration of a variety of measurement tools (e.g., peabody developmental motor scales, the movement assessment battery of children, Bruininks–Oseretsky test of motor proficiency) by trained personnel. While a wide range of fine motor skill assessments are available, there are limitations (e.g., time consuming, expensive, complex in its use) for their use by early childhood education practitioners, despite the fact that they are most likely to work with children on a daily basis and are normally responsible for planning and implementing educational programs. Current motor skill assessments (e.g., Peabody Developmental Motor Scales, the Movement Assessment Battery of Children) are poorly suited for this audience, as they are decontextualized from children's everyday activities, provide little information to educators about the diversity of fine motor abilities, and are often expensive and difficult to administer or can only be used by credentialed individuals. Current assessments are also not designed to support educators so that they become better able to observe and understand the growth of children's fine motor skills across various domains (e.g., fine motor precision, fine motor integration, bilateral coordination). The opportunity to provide educators with accurate fine motor skill assessment tools comes at a time when there is a substantial evidence base documenting positive associations, both concurrent and longitudinal, between various measures of children's fine motor skill and their development in other key areas of learning, such as cognition, school attainment and gross motor development (Cameron et al., 2012; Oberer et al., 2017; Strooband et al., 2020a, 2020b), along with the benefits of early identification and issuing educational intervention (Oberklaid et al., 2013).

Despite the need and opportunity to better respond to young children's fine motor skill development and learning needs, there is a lack of clarity about how best to describe and assess the various components of children's fine motor skills. Several overlapping terms have been used to describe the nature and complexity of fine motor skill and its components [e.g., manual dexterity, visual motor skills; see (Strooband et al., 2020a, 2020b)], yet there is little empirical basis to support effective differentiation of these fine motor components by early childhood educators. This lack of clarity contributes to difficulty identifying which skills are most indicative of children's abilities and developmental outcomes, as well as how to discern whether children's skills are improving. In the absence of a shared understanding about children's developmental attainment and appropriate tools to evaluate progress, many young children will continue to have unrecognised difficulties and delays, or their developmental needs will not be adequately catered to.

Currently within the literature, there are two predominant approaches to assess children's fine motor skills: performance-based tests and informant-based questionnaires (Matheis & Estabillo, 2018). Performance-based fine motor assessments usually incorporate numerous structured tasks for which children must perform activities involving visual motor skills (e.g., drawing to copy an image), manual dexterity (e.g., threading beads), and motor coordination skills (e.g., bouncing a ball). The Peabody Developmental Motor Scales (Folio & Fewell, 2000) and Bruininks–Oserestky Test of Motor Proficiency (Bruininks & Bruinicks, 2005) have been two of the most widely used assessments and both must be administered by trained examiners, thereby, often limiting accessibility of the tools to specific groups of professionals (e.g., researchers, occupational therapists).

Informant-based assessments collect ratings of children's fine motor skills by those who know them well or have multiple chances to observe them; they can be completed by parents, educators or researchers depending on the instrument and the context. These approaches are often used for large-scale research due to time efficiencies and cost-effectiveness. Notwithstanding these advantages, such methods are less feasible for establishing or evaluating interventions, and they are less informative when used to differentiate children's abilities for the purpose of educational planning or programming (Larkin & Cermack, 2002; Matheis & Estabillo, 2018). Furthermore, there are suggestions of biases in the results of informant-based assessment of children's development given that respondents (e.g., parents, educators) differ in their understanding of developmental progression and their ability to accurately situate a child's abilities along a continuum of development (Howard et al., 2019).

Despite the limitations of current assessment methods, there remain no validated assessments that focus on utility for those who work directly with young children in early childhood education and care (including preschool) contexts. Such an approach would have clear advantages in supporting differentiated programming while at the same time fostering greater understanding of children's fine motor development and associated practices amongst those with an opportunity to affect change in children's trajectories and outcomes.

There is therefore a need to develop a scalable, low-cost, and embedded way to support early childhood educators to identify fine motor skill development and delay, and thereby, foster children's development within the context of ongoing educational programs. This study reports on the development and initial evaluation of a novel early years fine motor skill assessment designed for use by early childhood education professionals but with the aim to match the psychometric properties of current performance-based assessments. This observational assessment tool, the *fine motor growth assessment* (FINGA), was designed to measure fine motor skill development in 3–5 years old children. Implementation and evaluation of this tool generated data to: (1) evaluate the construct validity and internal consistency of FINGA; (2) evaluate its concurrent validity with performance-based (e.g., Peabody Developmental Motor Scales, PDMS-2; (Folio & Fewell, 2000) and informant-based tools [e.g., Ages and Stages Questionnaire, ASQ-3; (Squires & Bricker, 2009)]; and (3) investigate and compare developmental sensitivity across the respective measures.

It was hypothesised that FINGA would: (a) show good construct validity and internal consistency; (b) correlate strongly with existing measures of fine motor ability; and (c) indicate good developmental sensitivity. Furthermore, based on the extant literature which generally shows that girls outperform boys on fine motor ability assessments (Comuk-Balci et al., 2016; Dinehart & Manfra, 2013; Strooband et al., 2020a, 2020b), this study also compared the performance of girls and boys.

Materials and Methods

Participants

Ninety-one children aged 3–5 years were recruited from seven early childhood education and care services within the Illawarra region of New South Wales, Australia. While the study was geographically constrained to the Illawarra area, the participating services were situated in communities with families from a wide range of socioeconomic and cultural backgrounds; falling within deciles 1–7 on the Australian Bureau of Statistics' Socioeconomic Indexes for Areas (ABS, 2008). In line with the distribution of ages of children attending these services, there were comparatively more 4-year-olds ($n = 41$; 43.9% girls) than 3-year-olds ($n = 24$; 54.2% girls) and 5-year-olds ($n = 26$; 57.7% girls). Participating children had no formal diagnoses of developmental delay. Prior to data collection, parent(s) or caregivers provided written informed consent and each child provided verbal assent to participate.

Measures

Fine Motor Growth Assessment (FINGA)

FINGA was developed to measure fine motor development of children aged 3–5 years by observing and rating their performance on two tasks that tapped different domains of fine motor skill ability through the completion of various activities: (1) an *individual* paper-plane building task, which was designed to engage and assess fine motor precision, fine motor integration, bilateral coordination, motor coordination, pencil grip and grapho-motor skills; and (2) a *group* copying-cards game task, which was designed to assess fine motor precision, fine motor integration, bilateral coordination, motor coordination, object manipulation and fine motor speed. Table 1 summarises the FINGA tasks and activities in relation to eight domains of fine motor skill ability. The tasks and domains were selected on the basis of a pilot process to evaluate acceptability and psychometric function of a range of potential items for inclusion. FINGA was designed to be engaging and consistent with activities and practices that occur in early childhood education contexts. Children were assessed in a quiet space at their preschool by the first

Table 1 FINGA observer rating overview for the individual (paper plane) and the group (copying-cards) tasks

Tasks (and activities)	1. Fine motor precision	2. Fine motor integration	3. Bilateral coordination	4. Motor coordination	5. Pencil grip	6. Grapho-motor skills	7. Object manipulation	8. Fine motor speed
Individual								
Name writing	x				x	x		
Drawing yourself	x	x			x	x		
Copying shapes	x	x			x			
Copying letters	x	x			x			
Cutting a line	x		x					
Folding paper	x		x	x				
Throwing plane			x	x				
Group								
Threading	x	x	x	x			x	x
Bricks (Lego)	x	x	x	x			x	x
Blocks	x	x	x				x	x

author, who led the design and development of FINGA. FINGA activities and scoring protocols are described below.

FINGA Individual Task: Paper-Plane The individual task was performed one-on-one and engaged children in a series of stepped activities necessitating writing, drawing, cutting, folding, and grasping. To begin, the facilitator displayed a completed paper-plane model to the child and asked the child if they wanted to build one just the same (all children agreed they did). Prior to each specific activity, the facilitator briefly explained the requirement of the task to the child; e.g., "Do you see the red box up here (point at red-box), can you try to write your name in the box?" (The script is available on request from first author). If children were unsure or hesitated for an extended period, which was rare, they were gently re-oriented to the task and the activity was explained again. The child had an assortment of drawing/writing utensils (i.e., pencils and markers) to support their activity but they chose which items to use themselves. Scissors were handed directly to the children for cutting. The stepped activities of the paper-plane creation were as follows: name writing; drawing yourself; copying three shapes; copying letters; cutting along a line; folding paper along multiple lines; and throwing the plane. There were minor alterations for each age group (i.e., 3-, 4- and 5-year-olds) to increase the level of difficulty. These included shape variation (i.e., line, circle, square and triangle) and the orientation of the cutting line. Table 1 shows which abilities the facilitator explicitly observed during each task. The duration of this activity varied from 4 to 10 min per child.

FINGA Group Task: Copying-Cards The group task was a building game in which children were presented with a picture of a block design made with threaded beads, LEGO™ blocks or wooden blocks. Children had to recreate the design with the relevant materials with complexity of design increasing as the game progressed. This task was administered in pairs incorporating activities with two children at a time. A constrained model was used here to ensure integrity at this level, nonetheless, future research will explore whether other groupings are equally possible. Building activities proceeded as follows: threading coloured shapes (4 trials of increasing complexity; i.e., increasing number of beads and smaller sized beads); building with LEGO™ (6 trials of increasing complexity; increasing the number of bricks and increasing the size and number of elements); and building with blocks (6 trials of increasing complexity; increasing the number of blocks and varying the positioning). As with the individual task, if children were unsure or hesitated for an extended period, which was rare, they were gently re-oriented to the task and the step was explained again. This task took approximately 20 min to complete, yielding a duration of 10 min per child.

FINGA Observer Scoring Sheet The FINGA observer scoring sheet (see "Appendix A") was designed for the assessment of eight discrete components of fine motor ability, (see Table 1): (1) fine motor precision (precise control and accuracy of hand and finger movements); (2) fine motor integration (use of visual perceptual skill in combination with correct hand/finger response); (3) bilateral coordination (coordination of both sides of the body effectively operating simultaneously); (4) motor coordination (combination of efficient pace and power with hand/finger movements); (5) pencil grip (competence and technique of grasping and holding a pencil); (6) grapho-motor skills (capacity of successful writing and drawing); (7) object manipulation (grasp and control of small object with hands and fingers); and (8) fine motor speed (time to successful completion of object manipulation tasks).

Each component was scored separately. A brief description of the target ability and examples of how observations should be used to make ratings of children's fine motor performance within the activities were included on the scoring sheet (see "Appendix A"). The facilitator rated each child individually, immediately on completion of the activity. Ratings were on a 5-point Likert scale; 1 indicated an inability to complete the task and 5 indicated excellent proficiency on the relevant ability.

Although there was some overlap between the two FINGA tasks, each one only engaged a subset of the fine motor components assessed (see Table 2). Components 1 to 4 were scored in both individual and group activities. Component 5 and 6 were only rated during individual activities (i.e., paper plane), and components 7 and 8 only during group activities (i.e., copying-cards game). Therefore, both tasks were rated for six fine motor skill ability components, which were then used to generate a fine motor score for each task; the average of the six components for the individual task (i.e., 1–4, 5 and 6) and the group task (i.e., 1–4, 7 and 8). While the properties of children's responses to these two different tasks were examined (see "Results"), there was no a priori reason based on the evidence to expect that the two tasks would discriminate specific aspects of children's abilities and, therefore, the possibility of creating an overall fine motor score (i.e., FINGA aggregated score) was examined.

Peabody Developmental Motor Scales—Second Edition (PDMS-2)

The PDMS-2 is a standardized assessment of children's gross and fine motor skills from birth through 5 years (Folio & Fewell, 2000). This study only utilized the fine motor components of the measure, which is divided into two subtests: grasping and visual-motor integration. The grasping subtest evaluates the ability to use hands, from holding an object to more controlled use of the fingers of both hands

Table 2 Descriptive statistics

	Total ($n=88$)	3-year-olds ($n=23$)		4-year-olds ($n=39$)		5-year-olds ($n=26$)	
	Mean (*SD*)	Mean (*SD*)	Range	Mean (*SD*)	Range	Mean (*SD*)	Range
FINGA aggregated	3.66 (0.89)	2.82 (0.83)	1.44–4.19	3.70 (0.74)	1.69–4.88	4.36 (0.40)	3.38–4.81
FINGA Individual	3.59 (0.98)	2.75 (0.93)	1.33–4.17	3.63 (0.89)	1.17–5.00	4.26 (0.50)	3.17–5.00
FINGA Group	3.70 (0.95)	2.81 (0.89)	1.50–4.67	3.75 (0.77)	2.00–5.00	4.43 (0.53)	3.17–5.00
PDMS Gr	49.00 (3.78)	45.70 (4.15)	39.00–52.00	49.51 (3.36)	38.00–52.00	51.20 (1.33)	47.00–52.00
PDMS VMI	132.98 (9.90)	122.52 (10.86)	96.00–135.00	134.76 (6.97)	105.00–143.00	139.76 (2.75)	133.00–144.00
PDMS STD	0.00 (1.78)	−1.93 (1.81)	−6.11 to 1.00	0.32 (1.31)	−3.21 to 1.81	1.26 (0.52)	−0.53 to 1.91
ASQ-3 Re	47.09 (12.40)	41.74 (12.12)	15.00–60.00	46.08 (13.75)	5.00–60.00	53.27 (7.34)	30.00–60.00
ASQ-3 Edu	47.30 (12.12)	39.21 (14.55)	10.00–60.00	47.94 (11.75)	15.00–60.00	53.04 (5.38)	45.00–60.00

(e.g., child touches each finger to thumb within 8 seconds). The visual-motor integration subtest measures the ability to use perceptual skills to perform eye-hand coordination tasks such as grasping objects and copying designs (e.g., folding paper in half twice with edges close to parallel). Each test item is scored as 2, 1 or 0, with specific requirements related to each item and 2 being the best performance. For the purpose of this study, raw scores for grasping and visual-motor integration, as well as a standardized (un-normed) score combining grasping and visual-motor integration, were used because of the interest in age related trends and direct comparison with FINGA (for which there is not normed data). The PDMS-2 Fine Motor Quotient was calculated on the basis of the standard scores within the PDMS manual for grasping and visual-motor integration so as to fully describe the sample. The current sample had a mean fine motor quotient of 101.57 ± 12.96, which indicated that it was, overall, a typically developing sample. The PDMS-2 fine motor component has excellent test–retest and interrater reliability (0.94 and 0.98, respectively; (Folio & Fewell, 2000). PDMS-2 validity has been well established, including internal consistency ($\alpha = 0.89–0.97$) and content validity (Folio & Fewell, 2000), as well as concurrent validity with the Movement Assessment Battery for Children ($r = 0.69$; (van Hartingsveldt et al., 2005). The fine motor components of the tool adopted for this study took 20–30 min to complete per child.

Ages and Stages Questionnaires, Third Edition (ASQ-3)

The ASQ-3 is a developmental screening tool of children's communication, gross motor, fine motor, problem solving, and personal-social abilities (Squires & Bricker, 2009). The current study only utilised the fine motor subtest, which consists of six items that vary for each age category (36, 42, 48, 54 and 60 months). For example, "Does your child unbutton one or more buttons?", which is only questioned with children at 48 and 54 months. For the purpose of this research, room leaders and trained researchers completed the fine motor subtest by scoring six items per child incorporating drawing, copying, cutting, and object manipulation tasks. Assessors scored the items as *not yet* (0 points), *sometimes* (5 points) or *yes* (10 points), based on children's ability to perform the activity consistently. The sum of the six items was used as an indicator of children's fine motor development. The ASQ-3 has established strong test–retest reliability (ICC range 0.75–0.82) and moderate inter-rater reliability (ICC range 0.43–0.69), as well as high overall concurrent validity (e.g. sensitivity = 86.1% and specificity = 85.6%; (Squires et al., 2009). The ASQ-3 took around 5–10 min to complete per child.

Procedure

All assessments were administered in a quiet space in the child's early childhood education and care service. Assessments were completed on the same day (or, where this was not possible, on the next possible day), with a minimum 30-min break between assessments. The FINGA activities were administered by the first author. The PDMS-2 and ASQ-3 were administered by experienced and trained data collectors who were blind to children's performance on FINGA. Data collectors had a minimum of 3 years of experience of collecting child development data using various tools, and for the purpose of this study participated in a one-day refresher training on the administration of PDMS-2 and ASQ-3. The FINGA activities were video recorded for the purpose of refining the FINGA protocols (e.g., scoring components and descriptions). The ASQ-3 room leader assessment was completed in the week after the researchers' visit to the early childhood service.

Results

Initial Data Exploration

The final dataset was screened for missing data. Three children did not participate in any of the measures due to early departure from their service ($n = 1$), or not providing verbal assent to participate ($n = 2$). Two children were missing ASQ-3 and PDMS-2 researcher ratings due to the leaving the service early on the day of assessment, and an inability to assess them at a later date. The final sample size used in the analyses included 88 children. Other missing data was due to educators ($n = 15$) not returning the ASQ-3. Missing data were excluded pairwise, because the primary aim of this study was evaluation of the FINGA tool.

Construct Validity and Internal Consistency

For the first four components (i.e., fine motor precision, fine motor integration, bilateral coordination, and motor coordination), which were scored on both the individual and group task, there were moderate inter-correlations between all component ratings (*r*s from 0.55 to 0.63, *p*s < 0.001). The dimensionality of the eight FINGA components was first examined separately within each task, and then after their combination, using exploratory factor analyses (EFA) with a maximum likelihood estimation and direct oblimin factor rotation. Adequacy of data for EFA analyses was demonstrated by: weak to strong associations between all 12 component ratings (i.e., six for each task; *r*s from 0.25 to 0.88); Kaiser–Meyer–Olkin (KMO) > 0.89; and significance in Barlett's tests of sphericity ($p < 0.001$). EFA results for both tasks separately indicated a one-factor solution as indicated by eigenvalues > 1 and screeplots. This factor explained 72% (individual: paper plane) and 81% (group: copying cards) of the variance in the data.

The FINGA total scores (i.e., mean scores of the six components per activity) for the individual and group tasks were strongly correlated ($r = 0.76$, $p < 0.001$). There was a non-significant difference [$t(87) = 1.64$, $p = 0.105$] in overall mean scores (see Table 2) between the individual and groups tasks. In light of these findings, a single score was generated for each of the first four components by averaging the rating from the two FINGA tasks. These average scores for components 1 through 4, along with the scores from the components rated in only one task (5 through 8), were then subjected to exploratory factor analysis (EFA). The EFA of the combined scores also indicated a one-factor structure that explained 73% of the variance. Reliability analyses confirmed the strong reliablity of this scale, Cronbach $\alpha = 0.94$. As such, a FINGA aggregated score based on the sum of the eight component scores used for the EFA was calculated for subsequent analyses.

Concurrent Validity

Bivariate correlations between the FINGA (aggregated, individual and group) and other fine motor assessments showed that the aggregated FINGA score was significantly, strongly and positively associated with each of the other fine motor measures: PDMS-2 standardized (STD) ($r = 0.84$, $p < 0.001$), ASQ-3 by researcher ($r = 0.69$, $p < 0.001$) and ASQ-3 by educator ($r = 0.72$, $p < 0.001$). Separately, the individual and the group tasks were correlated to a similar extent with the other fine motor measures (see Table 3). Further examination between FINGA ratings and the PDMS-2 fine motor subscales (i.e., grasping and visual motor integration) revealed moderate and strong positive correlations between aggregated FINGA scores and the raw scores of grasping ($r = 0.66$, $p < 0.001$) and visual-motor integration ($r = 0.83$,

Table 3 Concurrent associations between study variables

	1	2	3	4	5	6	7	8	9	10
1. FINGA—aggregated	–	0.94**	0.93**	0.69**	−0.11	0.66**	0.83**	0.84**	0.69**	0.72**
2. FINGA—individual	0.91**	–	0.76**	0.63**	−0.21	0.69**	0.79**	0.83**	0.75**	0.68**
3. FINGA—group	0.88**	0.62**	–	0.65**	−0.00	0.53**	0.78**	0.73**	0.57**	0.65**
4. Age	–	–	–	–	−0.05	0.59**	0.70**	0.72**	0.40**	0.44**
5. Sex	−0.12	-0.21	−0.01	–	–	−0.17	−0.13	−0.16	−0.30**	−0.08
6. PDMS-2 Gr	0.44**	0.54**	0.21	–	−0.15	–	0.59**	0.89**	0.62**	0.44**
7. PDMS-2 VMI	0.68**	0.64**	0.59**	–	−0.15	0.31**	–	0.89**	0.65**	0.64**
8. PDMS-2 STD	0.69**	0.73**	0.49**	–	−0.19	0.83**	0.79**	–	0.71**	0.61**
9. ASQ-3 researchers	0.64**	0.72**	0.43**	–	−0.33**	0.52**	0.56**	0.67**	–	0.61**
10. ASQ-3 educators	0.64**	0.58**	0.57**	–	−0.02	0.25*	0.52**	0.47**	0.53**	–

*$p < 0.05$; **$p < 0.01$, results of Pearson correlation are above the diagonal, and partial correlation controlling for age in months are below the diagonal

$p < 0.001$). Given the strong association between age and FINGA scores, the partial correlations were examined for the study variables controlling for age. While controlling for age did not alter the overall pattern of relations, the association between the FINGA group activity and the PDMS-2 grasping subscale did become non-significant.

Developmental Sensitivity

Linear regression analyses were used to investigate age effects on the FINGA score, and for the other fine motor measures. The aggregated FINGA scores showed a significant effect of age, $F(1, 86) = 76.16$, $p < 0.001$, $R^2 = 0.47$, $B_{std} = 0.69$. Also, significant age effects were found for: PDMS-2 STD, $F(1, 84) = 91.00$, $p < 0.001$, $R^2 = 0.52$, $B_{std} = 0.72$; ASQ-3 researcher-completed, $F(1, 84) = 15.64$, $p < 0.001$, $R^2 = 0.16$, $B_{std} = 0.40$; and ASQ-3 educator-completed, $F(1, 74) = 17.58$, $p < 0.001$, $R^2 = 0.19$, $B_{std} = 0.44$. Examining the FINGA tasks separately, age was a significant predictor for both the individual, $F(1, 86) = 57.39$, $p < 0.001$, $R^2 = 0.40$, $B_{std} = 0.63$, and group ratings, $F(1, 86) = 63.35$, $p < 0.001$, $R^2 = 0.42$, $B_{std} = 0.65$. There was a good distribution of FINGA scores by age, without ceiling or floor effects (see Table 2).

Sex Effects

Independent samples *t*-test were used to examine potential sex differences. FINGA aggregated scores did not show any sex differences, $F(1, 86) = 1.09$, $p = 0.300$, nor did the individual or group task. Similarly, the PDMS-2 STD, $F(1,84) = 3.50$, $p = 0.065$, and educator ASQ-3, $F(1, 74) = 0.138$, $p = 0.711$, did not show a significant sex effect. Only ASQ-3 ratings by the researcher, $F(1, 84) = 5.71$, $p = 0.019$, yielded a significant effect for sex and indicated that girls outperformed boys.

Discussion

The current study sought to examine the validity and reliability of a novel structured observational measure to assess young children's fine motor skills. Analyses of FINGA data indicated good concurrent validity when compared to two existing and validated fine motor measures (i.e., PDMS-2 and ASQ-3), as well as good internal consistency and age sensitivity. Overall, results revealed the FINGA approach was suitable to validly and reliably capture young children's fine motor skills during ecologically valid activities. While FINGA was specifically designed to engage a variety of fine motor abilities and their application to a variety of early years activities, results did not support a division of these abilities into empirically discrete fine motor components for the purpose of the current assessment.

While there are numerous validated fine motor skill assessments available to researchers and health specialists, they have not been specifically developed for use by early childhood education professionals. In response, FINGA was developed to respond to the unique advantages and opportunities that the early childhood education context presents, and which are not currently catered to with existing tools. Specifically, the benefits of using FINGA over existing measures includes: (1) being easily and freely accessible to a broader user base (e.g., researchers, early childhood practitioners, community health specialists, etc.); (2) reaching a large population of children due to the high proportion of children within early childhood education settings (3) having a lower completion time per child than other performance-based fine motor assessments; (4) capturing a wider range of children's fine motor abilities; (5) having a clear link to common activities within the early childhood education context and ecologically valid nature of the tasks; and (6) supporting the capacity to differentiate children based on ability and need so as to inform planning (e.g., individually tailored learning experiences) for children's learning and development. However, FINGA has yet to be validated in the hands of early childhood educators. Nonetheless, it is expected that FINGA can support the early childhood education context with early identification of fine motor difficulties, and therefore, shifting children's fine motor outcomes.

The current findings revealed that the aggregated FINGA score, as well as the separate task scores (*individual* and *group*), were successful approaches for measuring children's fine motor skills. FINGA also has the potential to provide educators with important qualitative information on various fine motor abilities through observation of children's performance on the different activities. Despite this potential, it is noteworthy that the factor analyses implied there was no strong evidence to systematically identify the fine motor ability components separately, from an assessment point of view. It is therefore important to ask whether so many separate components of fine motor skill need to be identified and scored. Previous research by Larkin and Cermack (2002) also highlighted the fact that other motor assessments struggle to identify separate factor loading when examining fine and gross motor tasks.

From a practice point of view, both early childhood educators and those more specialized in working with children who have fine motor delay, require information from children across a range of activities incorporating different movements or coordination patterns in order to develop a comprehensive understanding of fine motor capacity and to establish approaches or plans to support an individual child. In this sense, the FINGA activities provide a rich set of valid options for practitioners when trying to support an individual child. It is also important to note that the FINGA approach was validated on a sample of typically developing children and it may be, in subsequent research, that the different components of fine motor ability take on more individual significance within sub-groups of children experiencing fine motor delay or impairment.

Currently, performance-based fine motor assessments face some challenges because of a lack of developmental sensitivity (Larkin & Cermack, 2002; Matheis & Estabillo, 2018) and population biases (van Hartingsveldt et al., 2005). Assessments like PDMS-2, for example, primarily use quantitative outcome-based data to rate children's performance, which might not bring to light whether children use their fine motor skills correctly to obtain the correct activity outcome (Larkin & Cermack, 2002; Matheis & Estabillo, 2018). Thus, those administering the PDMS-2 within the current study identified that in some cases children received high ratings even though they executed the tasks abnormally; e.g., holding scissors unusually (fine motor skill performance), yet cutting straight lines (activity outcome). This limitation has also been highlighted in previous work (Matheis & Estabillo, 2018), suggesting such assessment strategies (i.e., based on activity outcome rather than fine motor skill performance) lack accuracy.

The fine motor component of the PDMS-2 has been found to lack sensitivity in certain populations. Findings by van Hartingsveldt et al. (2005), for example, showed that out of a group of 18 Dutch children with fine motor problems, according to the teachers, only seven children were identified by the PDMS-2 as having fine motor problems. Children were also tested on manual dexterity with the Movement Assessment Battery for Children using Dutch standards, which indicated 14 children with fine motor problems. The inconsistency between such results of performance-based assessments may be caused by practical inaccuracy of tests or cultural invalidity of measures.

In light of these issues with existing performance-based assessments, there are some clear research opportunities for those using the FINGA tool to improve consistency and sensitivity in the identification of children with fine motor delay. Importantly, the FINGA tool uses fine motor skill performance rather than activity outcomes to rate children's developmental attainment. Furthermore, the principles which have given rise to the FINGA tool approach (outlined above) mean that it will be easier to collect and share large data sets that reflect greater diversity; FINGA by no means addresses issues of cultural validity but it provides a means to develop bespoke data sets for specific populations or within specific conditions.

Despite these factors, it is critical to recognize that the FINGA tool does not seek to replace existing assessments or undermine the expertise of professionals (e.g., Occupational Therapists) working in this domain. Rather, it is the hope of the authors that enabling formal assessment of fine motor development through universal early childhood services will increase awareness of children's needs and abilities, facilitate earlier identification and referral, and empower early childhood educators to better support children's learning and development both independently and in collaboration with allied health professionals.

Finally, while there is some evidence suggesting girls have more advanced fine motor skills than boys at equivalent ages (Comuk-Balci et al., 2016; Dinehart & Manfra, 2013; Strooband et al., 2020a, 2020b), no evidence was found in the current study to support this hypothesis. PDMS-2 and educator-ASQ did now show any gender effects. Nonetheless, ASQ scores completed by researchers did highlighted that girls performed better than boys. Interestingly, FINGA also did not reveal any differences between girls and boys. It is possible that this is because the selected universal tasks children had to perform during the assessment were based on typical everyday preschool activities.

Conclusion

The initial findings regarding the viability of FINGA are promising, showing very good internal consistency and age sensitivity, as well as good concurrent validity when compared to two already validated fine motor assessments. There are still several stages, such as testing the inter-rater reliability of the FINGA, that need to be completed before use should be extended and scaled to ECEC practitioners. As described by Larkin and Cermack (2002), reliable ratings may require extensive training for practitioners to meet observational guidelines and tactics. However, FINGA will follow an existing model (Howard et al., 2018) from which to design and deliver assessment training freely to a broad user base entailing online training with reliability control ((Howard et al., 2019): PRSIST). This situates FINGA within a successful model of delivery and scale, which has already been translated to use in educational and research settings around the world. FINGA in the hands of practitioners has the potential to provide deeper knowledge on fine motor skills and the trajectories of children's fine motor development. This information can help practitioners identify children who may be experiencing delay or difficulty in fine motor skills, and as such provide them with educational tailored support strategies or refer children to specialists (e.g., Occupational Therapist) for further examination.

Appendix A

Fine Motor Growth Assessment (FINGA)
OBSERVER SCORING SHEET

Child Name/ID: __________________ **Child Sex: M/F** **Child Age:** _____ **Rater:** ___________ **Date:** ____ /____ /______
Activity Rated: Individual Paper-plane - Group Coping-cards

Rater Notes:

1. Fine Motor Precision	1	2	3	4	5

This component focuses on the child's precision and attention for detail during the activity. To rate this component, you have to observe the child's precise control of hand and finger movements. *Regarding the plane activity*, does the child stay within the borders while writing, drawing, cutting and folding? At a score of 1, a child repeatedly performs outside of the boxes/borders of the task. At a score of 5, a child pays close attention to detail in each component and stays within boundaries all the time. *Regarding the copying-cards activity*, does the child close attention for detail and places the blocks, bricks and beads accurately, as on the card? At a score of 1, a child repeatedly misplaces objects. At a score of 5, a child pays close attention for the position off each object and ensures it is exactly in the right place.

2. Fine Motor Integration	1	2	3	4	5

This component focuses on the integration of visual perceptual abilities with the correct fine motor response during the activity (also known as visual motor integration). To rate this component, you have to observe children's use of their eyes in combination hands and fingers. *Regarding the plane activity*, what is the child's ability of drawing themselves and reproducing shapes? At a score of 1, a child is not able to draw themselves or copy shapes, nor letters. At a score of 5, a child is mindful when drawing him-/herself and is capable to accurately copy shapes and letters. *Regarding the copying-cards activity*, what is the child's ability of grasping objects and using these to build and reproduce specific designs? At a score of 1, a child is not able to reproduce any designs after carefully looking at them. At a score of 5, a child is thoughtful when inspecting cards, which reflects to accurate reproduction of designs.

3. Bilateral Coordination	1	2	3	4	5

This component focuses on the coordination of both sides of the body working simultaneously during the activity. To rate this component, you have to observe the children's ability to use both sides of the body, arms, hands and fingers, at the same time in a controlled and efficient manner. *Regarding the plane activity*, does the child make use of both hands during cutting and folding in an efficient and controlled way? *Regarding the copying-cards activity*, does the child uses both sides of the body simultaneous to organize the objects effectively? For plane and copying-cards activity, at score of 1, a child does not use his/her non-dominant hand during any point in the activity to assist the dominant hand. At score of 5, a child's non-dominant makes contribution during the activity by assisting the dominant hand, which results in more accurate and controlled movements.

4. Motor Coordination	1	2	3	4	5

This component focuses on the child's ability to match their arm and hand movements with pace and power during the activity in a coordinated way. To rate this component, you have to observe children's competences of using objects with the correct force (e.g. finger strength). *Regarding the plane activity*, does the child have control when using a pencil or throwing the plane? At score of 1, a child has poor pencil control or difficulties holding and throwing paper plane. At score of 5, a child has great pencil control and is able to hold and throw the plane with force. *Regarding the copying-cards activity*, does the child have control when pushing bricks together or when threading? At score of 1, a child is not able to push bricks together, nor able to tread. At score of 5, a child pushed bricks and threads with ease.

5. Pencil Grip (Plane only**)**	1	2	3	4	5

This component focuses on the child's ability to grasp and hold a pen or pencil during the plane activity. To rate this component, you have to observe children's technique when grasping a pen or pencil and their skills to move the hand while holding the pen or pencil. *Regarding the plane activity*, what kind of pencil grip (e.g. cylindrical, digital, modified tripod or tripod grasp) uses the child during writing and drawing? At score of 1, a child has a cylindrical grasp (e.g. holds the pen as an hammer) and shows no controlled movements. At score of 5, a child has a tripod grasp (e.g. three-finger grip, where pen or pencil is in between thumb and index finger while resting on the middle finger) and has smooth control over the movement of the pen or pencil.

6. Grapho-motor Skills (Plane only**)**	1	2	3	4	5

This component focuses on the child's ability to combine motor, cognitive and perceptual skills to be able to write and draw during the plane activity. To rate this component, you have to observe the children's manual operation of a pen or pencil during writing or drawing about themselves. *Regarding the plane activity*, does the child define his/her thoughts through writing or drawing? At score of 1, a child is not able to write his/her name or draw any parts of his-/herself. At score of 5, a child is able to form letters from his/her name and draw parts of themselves.

7. Object manipulation (Copying only**)**	1	2	3	4	5

This component focuses on the child's ability to grasp and control small objects with their hands during the copying-cards activity. To rate this component, you have to observe the children's competences to control the movements of small objects with their hands. *Regarding the copying-cards activity*, can the child grasp objects and manipulate these with care? At score of 1, a child is not capable of grasping small objects or is continues dropping objects. At score of 5, a child has great ability of grasping small objects and moving these objects within one or between two hands.

8. Fine Motor Speed (Copying only**)**	1	2	3	4	5

This component focuses on the child's ability to manipulate objects in a quick but coordinated manner. To rate this component, you have to observe the time it takes children to complete a task successfully. *Regarding the copying-cards activity*, how long does it require for a child to complete the task correctly? At score of 1, a child requires excessive amount of time to complete a single design. At score of 5, a child completes designs rapidly without reducing their accuracy and control during the task.

Acknowledgements The authors thank all preschool children, educators, directors and other staff members for participating in the study.

Funding Open Access funding enabled and organized by CAUL and its Member Institutions. This study was funded by Early Start and the Faculty of the Arts, Social Sciences and Humanities at the University of Wollongong.

Declarations

Conflict of interest The authors have indicated they have no potential conflict of interest to disclose.

References

ABS. (2008). Information paper: An introduction to socio-economic indexes for areas (SEIFA), 2006. Retrieved from https://www.abs.gov.au/ausstats/abs@.nsf/mf/2039.0

Bello, A. I., Quartey, J. N., & Appiah, L. A. (2013). Screening for developmental delay among children attending a rural community welfare clinic in Ghana. *BMC Pediatrics, 13*, 119. https://doi.org/10.1186/1471-2431-13-119

Bruininks, R. H., & Bruinicks, B. D. (2005). *Bruininks-Oseretsky test of motor proficiency, second edition (BOT-2)*. Pearson.

Cameron, C. E., Brock, L. L., Murrah, W. M., Bell, L. H., Worzalla, S. L., Grissmer, D., & Morrison, F. J. (2012). Fine motor skills and executive function both contribute to kindergarten achievement. *Child Development, 83*(4), 1229–1244. https://doi.org/10.1111/j.1467-8624.2012.01768.x

Caramia, S., Gill, A., Ohl, A., & Schelly, D. (2020). Fine motor acitivities in elementary school children: A replication study. *American Journal of Occupational Therapy*. https://doi.org/10.5014/ajot.2020.035014

Comuk-Balci, N., Bayoglu, B., Tekindal, A., Kerem-Gunel, M., & Anlar, B. (2016). Screening preschool children for fine motor skills- environmental influence. *Journal of Physical Therapy Science, 28*, 1026–1031. https://doi.org/10.1589/jpts.28.1026

Dinehart, L., & Manfra, L. (2013). Associations between low-income children's fine motor skills in preschool and academic performance in second grade. *Early Educudation and Development, 24*(2), 138–161. https://doi.org/10.1080/10409289.2011.636729

Folio, M., & Fewell, R. R. (2000). *Peabody developmental motor scales* (2nd ed.). Pro-Ed.

Handel, A. J., Lozoff, B., Breiilh, J., & Harlow, S. D. (2007). Sociodemographic and nutritional correlates of neurobehavioral development—a study of young children in a rural region of Ecuador. *Pan American Journal of Public Health, 21*(5), 292–300. https://doi.org/10.1590/s1020-49892007000400004

Howard, S. J., Neilsen-Hewett, C., de Rosnay, M., Vasseleu, E., & Melhuish, E. (2019). Evaluating the viability of a structured observational approach to assessing early self-regulation. *Early Childhood Research Quarterly, 48*, 186–197. https://doi.org/10.1016/j.ecresq.2019.03.003

Howard, S. J., Vasseleu, E., Neilsen-Hewett, C., & Cliff, K. (2018). Evaluation of the preschool situational self-regulation toolkit (PRSIST) program for supporting children's early self-regulation development: Study protocol for a cluster randomized controlled trial. *Trials, 19*(1), 64–64. https://doi.org/10.1186/s13063-018-2455-4

Larkin, D., & Cermack, S. A. (2002). Issues in identification and assessment of developmental coordination disorder. In D. L. S. A. Cermak (Ed.), *Developmental coordination disorder* (pp. 86–102). Singular Publishing Group.

Luo, Z., Jose, P. E., Huntsinger, C. S., & Pigott, T. D. (2007). Fine motor skills and mathematics achievement in East Asian American and European American kindergartners and first graders. *British Journal of Developmental Psychology, 25*(4), 595–614. https://doi.org/10.1348/026151007x185329

Marr, D., Cermak, S., Cohn, E. S., & Henderson, A. (2003). Fine motor activities in head start and kindergarten classrooms. *American Journal of Occupational Therapy, 57*(5), 550–557. https://doi.org/10.5014/ajot.57.5.550

Matheis, M., & Estabillo, J. A. (2018). Assessment of fine and gross motor skills in children. *Handbook of childhood psychopathology and developmental disabilities assessment* (pp. 467–484). Springer.

Oberer, N., Gashaj, V., & Roebers, C. M. (2017). Motor skills in kindergarten: Internal structure, cognitive correlates and relationships to background variables. *Human Movement Science, 52*, 170–180. https://doi.org/10.1016/j.humov.2017.02.002

Oberklaid, F., Baird, G., Blair, M., Melhuish, E., & Hall, D. (2013). Children's health and development: Approaches to early identification and intervention. *Archives of Disease in Childhood, 98*(12), 1008–1011. https://doi.org/10.1136/archdischild-2013-304091

OECD. (2016). Enrolment rate by age. Retrieved from https://stats.oecd.org/viewhtml.aspx?datasetcode=EAG_ENRL_RATE_AGE&lang=en

Squires, J., & Bricker, D. (2009). *Ages & stages questionnaires (ASQ-3): A parent-completed child-monitoring system*. Brookes Publishing Company.

Squires, J., Twombly, E., Bricker, D., & Potter, L. (2009). *ASQ-3 technical report*. Brookes Publishing.

Strooband, K. F. B., de Rosnay, M., & Okely, A. D. (2020a). Prevelance and risk factors of pre-schoolers' fine motor delay within vulnerable Australian communities. *Journal of Paediatrics and Child Health, 57*(1), 114–120. https://doi.org/10.1111/jpc.15152

Strooband, K. F. B., de Rosnay, M., Okely, A. D., & Veldman, S. L. (2020b). Systematic review and meta-analyses: Motor skill interventions to improve fine motor development in children aged brith to 6 years. *Journal of Developmental Behavioral Pediatrics, 41*(4), 319–331. https://doi.org/10.1097/dbp.0000000000000779

Troude, P., Squires, J., L'Helias, L. F., Bouyer, J., & de La Rochebrochard, E. (2011). Ages and stages questionnaires: Feasibility of postal surveys for child follow-up. *Early Human Development, 87*(10), 671–676. https://doi.org/10.1016/j.earlhumdev.2011.05.007

van Hartingsveldt, M. J., Cup, E. H. C., & Oostendorp, R. A. B. (2005). Reliability and validity of the fine motor scale of the peabody developmental motor scales-2. *Occupational Therapy International, 12*(1), 1–13. https://doi.org/10.1002/oti.11

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.