mHealth developmental screening for preschool children in low-income communities

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Abstract

Children are often only identified with a developmental delay when they enter primary school due to developmental delays hindering academic progress. Detection of at-risk children in low-income communities is typically unavailable due to several challenges. This study validated an mHealth-based developmental screening tool as a potential time- and cost-effective way of delivering services for preschool children. This cross-sectional within-subject study screened 276 preschool children from low-income communities using the mHealth Parents' Evaluation of Developmental Status (PEDS) tools. The mHealth PEDS tools' performance was then evaluated by comparing caregiver concerns according to the PEDS tools with results obtained using a reference standard assessment tool, the Vineland-3. The mHealth PEDS tools identified 237 (85.9%) of children at risk of developmental delay compared to 80.1% (n = 221) of children identified with a developmental delay using the Vineland-3. Sensitivity of the PEDS tools was high (92.6%) with low specificity (22.5%) using US standardised criteria. Literacy skills were found to be most delayed, according to the PEDS: DM (89.3%; n = 142) and Vineland-3 (87.1%; n = 134). Low specificity of the prescribed criteria may require the implementation of adapted referral criteria within low socio-economic status (SES) settings. The mHealth PEDS tools may still be valuable for preschool developmental surveillance of children within low SES settings. It is recommended, however, that children who are identified with a developmental concern undergo a second screen to reduce false positives.

Keywords
Early childhood development, low- and middle-income countries, Parents' Evaluation of Developmental Status tools, screening, telehealth

Introduction

In 2018, 5.3 million children under five died, mostly due to poor healthcare and environmental risks (UN Inter-agency Group, 2018). The quadruple burden of disease (QBD) in South Africa annually accounts for 51 000 under five deaths in the country (Day et al., 2018) which includes diseases of maternal, newborn and child health, HIV/AIDS and tuberculosis, non-communicable diseases and violence and injury (Pillay-van Wyk et al., 2016). In response to high mortality rates, health systems primarily focus on child survival while child development remains a low priority (Johnson et al., 2019). Yet, more than triple the amount (35%) of children in low- and middle-income countries (LMICs) have developmental delays (Miller et al., 2015) when compared to children (7%) in the United States (Zablotsky et al., 2017). Global disparity of developmental delays and high prevalence rates in young children have been widely acknowledged as drivers advocating early identification and intervention to prevent delays and disorders in LMICs (Mello et al., 2016).

Early identification (EI) and intervention of developmental delays are associated with improved outcomes in neurocognitive ability, theory of mind, attention regulation (Simanowski and Krajewski, 2019), literacy and language development (Milner et al., 2019). Late identification and lower socio-economic status (SES), however, may impact these abilities greatly. A gap exists in developmental outcomes and academic abilities amongst preschool-aged children from low versus high SES (Suskind et al., 2016), with poorer academic abilities in children with lower SES being evident (Blair and Raver, 2016). Apart from SES, caregiver-child interactions and caregiver knowledge are directly linked to developmental outcomes, especially in preschool children (Pattison and Dierking, 2018).

Parents report more developmental concerns for children older than three years than for their younger counterparts (van der Merwe et al., 2019). This may be due to caregivers noticing that their children are not ready for the academic demands upon school entry (Willoughby et al., 2017). Developmental outcomes including language, cognition (Guralnick, 2013), adaptive functioning and social skills are most affected by late diagnosis of delay, i.e. preschool age, as the critical period for neuroplasticity has passed (Harrison et al., 2017; Benevides et al., 2018). Yet, these skills are essential for academic success (Duncan and Magnuson, 2013; Nesbitt et al., 2015; Simanowski and Krajewski, 2019). Unfortunately, detection of at-risk children in low-income communities is typically unavailable, due to several challenges, including inaccessibility of services and a lack of appropriate developmental screening measures. mHealth tools may offer an alternative way for providing access to developmental screening services to children and caregivers, within any setting.

Globally, there is growing evidence supporting the use of information and communication technologies, including mHealth, particularly in resource-poor settings of LMICs (Chib et al., 2015; Zapata et al., 2015; Hamine et al., 2015; Chanani et al., 2016). In South Africa, an mHealth supported hearing and vision screening programme was successfully facilitated by lay health workers across 271 preschools and reached 8023 children. It proved to be a cost-effective, scalable model and created awareness amongst preschool staff, caregivers and community members (Eksteen et al., 2019). mHealth services for caregivers and their children show promise to make screening accessible and affordable within community-based settings. An mHealth developmental screening tool can provide remote access to effective developmental surveillance to reduce barriers to developmental care

(Johnson et al., 2019). It may also contribute to more comprehensive community-based services for children in low-income communities (Eksteen et al., 2019).

The PEDS tools is available as a smartphone-based mHealth developmental screening tool, which consists of the Parents' Evaluation of Developmental Status (PEDS) (Glascoe, 2013) and PEDS: Developmental Milestones (PEDS:DM) (Glascoe and Robertshaw, 2007). mHealth PEDS tools have been validated in the South African context, for children below 42 months (Abdoola et al., in press; Maleka et al., 2016). A 99% agreement rate between the caregiver-completed smartphone application and original paper-based PEDS tools were reported (Maleka et al., 2016). It was successfully implemented in a low-income South African community for children below the age of 36 months (van der Merwe et al., 2019). The mHealth PEDS tools can be implemented within settings such as schools, clinics and during home visits, with the paper-based tools being validated for children up to the age of seven years, 11 months (Glascoe, 2013; Glascoe and Robertshaw, 2007).

Validating the mHealth PEDS tools for an older age cohort (42-83 months) for the South African context could enable quality developmental screening to vulnerable preschool children and their families in a decentralised service-delivery model (van der Merwe et al., 2019). A validated mHealth-based developmental screening tool may provide a viable alternative to time consuming, paper-based developmental services for preschool children.

Aims

To validate the performance of an mHealth-based developmental screening tool for children between 36 and 83 months against a standardised developmental assessment instrument. The study further aimed to determine whether a significant association across referral criteria exists.

Method

Study design

A cross-sectional research design was employed (Leedy and Ormrod, 2015). Probability, stratified random sampling was implemented (Leedy and Ormrod, 2015). This was used to ensure that each age cohort, as assigned according to the age categories in the PEDS: Developmental Milestones (PEDS: DM) screening tool, were equally represented in the sample population.

Setting and sample population

Data were collected in the eastern suburbs in the City of Tshwane, in settings affected by, amongst others, poverty, unemployment and undernutrition. These suburbs included Eersterust, Nellmapius, Mamelodi and Willowlane Village and are within a 20 km radius from one another. Approximately 15% of the City of Tshwane population are housed within these communities (Statistics South Africa, 2012). Approximately 40% of people in these communities are unemployed and earn no monthly income (Statistics South Africa, 2012).

Convenience sampling was used to identify and select early childhood development (ECD) centres from the respective communities. Children from the ECD centres in the study are part of a high risk, vulnerable ECD population. These ECDs are mostly run from the ECD principal's house with ECD practitioners not formally trained in providing ECD services. ECD centres that were involved in the study gave permission to contact caregivers who met the inclusion criteria. Inclusion criteria required caregivers to have a child between three years and six years 11 months in order to participate in this research study. Furthermore, caregivers and children had to live in the same household and only one child per caregiver were included in the research study. Caregivers were also required to have conversational English abilities in order to complete the background information questionnaire and Vineland-3 caregiver-completed assessment form.

Bias

Sampling bias may have occurred, as only ECD centres in poverty-stricken, low-income communities were involved in the research study. This was done in order to study childhood development of populations that are affected by poverty and limited developmental resources. By using a variety of ECD centres within the community, omission bias was controlled for.

Materials and apparatus

mHealth PEDS tools consist of 16 to 18 multiple choice questions and take approximately 10-15 minutes to complete. PEDS tools were developed into a smartphone application using the same algorithm as the original paper-based tool (Glascoe, 2013), for children aged birth to 42 months (Maleka et al., 2016). According to the Landis and Koch-Kappa's Benchmark Scale, almost perfect agreement (κ=0.99; Cohen's Kappa coefficient) was found between the screening outcome, administered by a community health worker, and the paper-based version, administered by a Speech-Language therapist (Maleka et al., 2016). Questions asked in the mHealth

PEDS tools are prescriptive and phrased in as it should be presented to the caregiver. Elaborations and examples were built into the questions during initial development of the PEDS: DM (Glascoe and Robertshaw, 2007). Multiple but specific options are provided to the caregiver by means of a dropdown list and the most relevant answer should be selected. mHealth PEDS tools have previously been used within a setting much like Mamelodi (van der Linde et al., 2016; Maleka et al., 2016; van der Merwe et al., 2019). According to caregiver reports obtained during these studies no comments about questions being unclear were raised, which may suggest their appropriateness in this type of setting (van der Merwe et al., 2019; Maleka et al., 2016).

Developmental outcomes are interpreted using five evidence-based pathway referral algorithms, which either pass or refer a child based on type and/or amount of parental concerns (Glascoe, 2013):

- Path A: Two or more predictive concerns. Immediate referral for diagnostic assessment
- Path B: One predictive health concern. Second screen recommended
- Path C: Non-predictive concerns. Provide counselling
- Path D: Caregivers have difficulty communicating their concerns
- Path E: Low-risk path. No caregiver concerns noted and therefore screening is deemed a pass.

Children fail the mHealth PEDS tools when they receive a Path A result on the PEDS, or when they fail one or more developmental domains on the PEDS: DM (Glascoe, 2013).

Recently, the mHealth PEDS tools were updated and developed for children up to 7 years, 11 months. This updated version of the mHealth PEDS tools uses the same algorithm as the original paper-based tool and the previous version of the application. For the purpose of this study, the updated version of the application-based tools were used. The updated version of the application was developed by an independent programmer and is piloted by the University of Pretoria. It was written as a native Android application in Java making use of the Android Software Development Kit (SDK).

The Vineland Adaptive Behavior Scales, Third Edition (Vineland-3) (Sparrow et al., 2016) is a measure for evaluation of adaptive functioning for individuals from birth to age ninety. Administration time can vary from 10 to 40 minutes, depending on the administration format selected (Pepperdine and McCrimmon, 2017). The Vineland-3 consists of a comprehensive and domain-level version which are either completed by a caregiver, healthcare professional or teacher and comprise four core domains (communication, daily living skills, motor skills and socialization) as well as 11 subdomains. The tool was standardised on a normative sample of 2 560 individuals. It has an internal consistency ranging between .86 to .99 and test-retest reliability (*r*-value) ranging between .62 and .94 (Pepperdine and McCrimmon, 2017). For this study, the Vineland-3 Comprehensive caregiver form was completed by each caregiver.

All participants were asked to complete a background information questionnaire, in order to obtain their demographic and biographic information for an accurate description of the sample population. An existing questionnaire was amended (van der Linde et al., 2015; van der Merwe et al., 2019).

Procedures

Institutional Review Board approval was obtained for this study, from the Humanities research ethics committee, University of Pretoria, South Africa (approval number: GW20180626HS). Seven ECD centres in the involved communities gave permission to contact caregivers for possible participation in the current study. The researcher contacted caregivers, who met the inclusion criteria, through the ECD centres. Data were collected during quarterly parent evenings or information sessions as scheduled by the respective ECD centres. Caregivers were provided with information regarding the aim of the study and procedures that will be followed. After the information session, caregivers who met the inclusion criteria and who volunteered to participate in the research study provided informed consent.

Once informed consent was obtained, caregivers completed the background information questionnaire. Thereafter, the mHealth PEDS tools developmental screening was conducted. After developmental screening the Vineland-3 Comprehensive Caregiver form was given to participating caregivers to complete at home. After approximately one week, the Vineland-3 forms were fetched from the ECD centre to be scored and compared to the mHealth PEDS tools results. This procedure was implemented randomly at selected ECD centres. At some ECD centres, the Vineland-3 Comprehensive Caregiver form was completed and returned prior to mHealth PEDS tools developmental screening.

After results were analysed and processed, caregivers and ECD centres (upon caregivers' permission) received results via sms. Based on the Vineland-3 results, if a child was identified as having a developmental delay, they were referred to relevant healthcare professional(s). The mHealth PEDS tools' performance was then evaluated by comparing caregiver concerns according to the mHealth PEDS tools with results obtained using the reference standard, Vineland-3.

Data analysis

The mHealth PEDS tools data were stored automatically and scores were generated through an evidence-based algorithm. Vineland-3 raw scores were converted to v-scale scores for each developmental domain and were used to determine whether a child passed or failed a developmental domain. A developmental domain was considered delayed when a participant scored one standard deviation (three points) below the mean of 15. A developmental delay was diagnosed using the Vineland-3 outcome when two or more developmental domains were delayed (Sparrow et al., 2016).

The IBM Statistical Package for the Social Sciences (SPSS) version 24 (Chicago, Illinois) was used for statistical calculations and analysis. Descriptive statistics, i.e. median, mean, IQR, SD and frequencies, were used to describe the sample population.

The aim of this study was to evaluate the performance of the mHealth PEDS tools in terms of sensitivity, specificity and positive and negative predictive value and were determined by employing Chi-Square test of association. Prescribed referral criteria of the mHealth PEDS tools (as set out by the author of the PEDS tools) and several adapted referral criteria (RC) were employed to determine its effect on the sensitivity and specificity of the mHealth PEDS tools (Maleka et al., 2019). Prescribed criteria of the mHealth PEDS tools refer a child when PEDS Path A result is obtained, irrespective of PEDS: DM result. Path B-E is dependent on PEDS: DM result. When a child fails one or more developmental domains on the PEDS: DM a refer result is reported. RC1 states the same referral criteria, but two or more developmental domains on PEDS: DM justifies referral. RC2 requires referral of three or more developmental domains when using the PEDS: DM.

Independent Samples *t*-test and 95% Confidence Intervals (CI) of 95% with mean difference (M) as point estimates were used to determine whether developmental concerns were significantly different across age. Convergent validity was also determined and ETA correlation ratio (η) with 95% CI was used to determine strength and direction of associations between the PEDS tools and Vineland-3 developmental domains. A power analysis was conducted using the G*Power software v 3.1.9.4 and found that a minimum sample size of n=17 per age cohort was required for a power of at least 0.80.

Results

Data collection took place at seven participating ECD centres during a quarterly scheduled parent evening or information session held by the respective ECD centres. Caregivers with children were invited to participate in the study (n=287), of which 11 participants were excluded due to incomplete data sets. Therefore, a sample of 276 participants with children between the ages of three years and six years 11 months (median age = 50.00; IQR = 21.00) were included in the study (Figure 1). Child gender was similarly distributed, with 150 (54.3%) children being female and 126 (45.7%) male. Most of the children in the current study were exposed to at least three developmental risks (98.6%; n=272), including caregiver unemployment, single caregiver-headed households and low caregiver education levels.

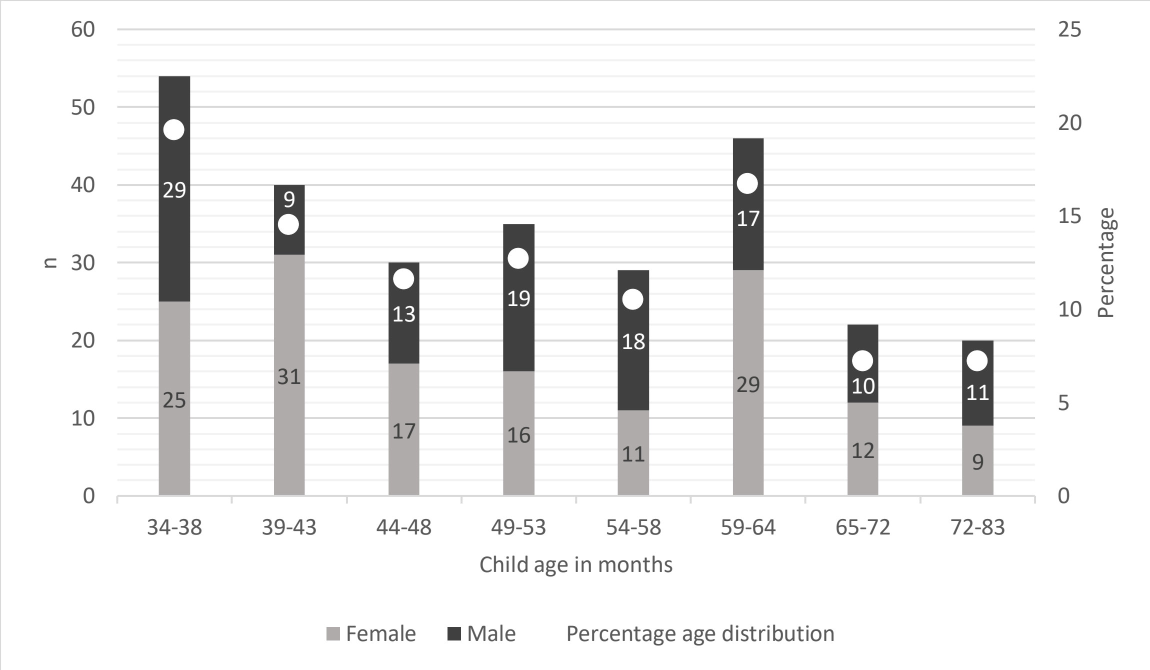

Figure 1. Gender and age distribution across participants according to PEDS: DM age categories

The mHealth PEDS tools identified 237 (85.9%) of children at risk of developmental delay. The prevalence of children identified with a developmental delay using the Vineland-3 was 80.1% (221/276). Sensitivity of the mHealth PEDS tools decreased (92.6% for prescribed criteria to 74.4% for RC2) as number of developmental domains on PEDS: DM increased. Specificity, however, increased (22.5% to 46.4%), but remained low (Table 1). Across the various referral criteria, Positive Predictive Value (PPV) remained high (82.8% to 84.7%) with lower Negative Predictive Value (NPV) (31.3% to 40.7%) (Table 1).

Table 1. Performance of the mHealth PEDS tools compared to the Vineland-3 across different referral criteria (RC) (n=276)

Referral criteria	Referral rate	Sensitivity	95% CI (for sensitivity)	Specificity	95% CI (for specificity)	NPV † (%)	PPV‡ (%)	95% CI (PEDS tools vs Vineland-3)
Prescribed criteria*	85.9%	92.6%	88.2, 95.7	22.5%	11.8, 36.6	40.7	84.0	.000, .018
RC1**	83.5%	86.6%	81.4, 90.7	28.6 %	17.3, 42.2	34.8	82.8	.062, .134
RC2***	70.3%	74.4%	68.2, 80.0	46.4 %	33.0, 60.3	31.3	84.7	.010, .051

* Prescribed criteria: Path A refer. Path B-E dependent on PEDS: DM (one or more developmental domains refer)

** RC1: Path A refer. Path B-E dependent on PEDS: DM (two or more developmental domains refer)

*** RC2: Path A refer. Path B-E dependent on PEDS: DM (three or more developmental domains refer)

† NPV: Negative Predictive Value- Probability that a delay is not present when the screen was passed

‡ PPV: Positive Predictive Value- Probability that a delay is present when the screen was failed

Developmental domain-specific outcomes between the mHealth PEDS tools and a reference standard, the Vineland-3, are depicted in Figure 2. The PEDS domain with highest failure rate was adaptive behaviour (25.0%; n= 66) with the PEDS: DM also showing a high failure rate in this domain (55.7%; n= 147). According to the Vineland-3 and PEDS: DM, most children had a delay in literacy skills (87.1 %; n= 134 and 89.3%; n= 142 respectively).

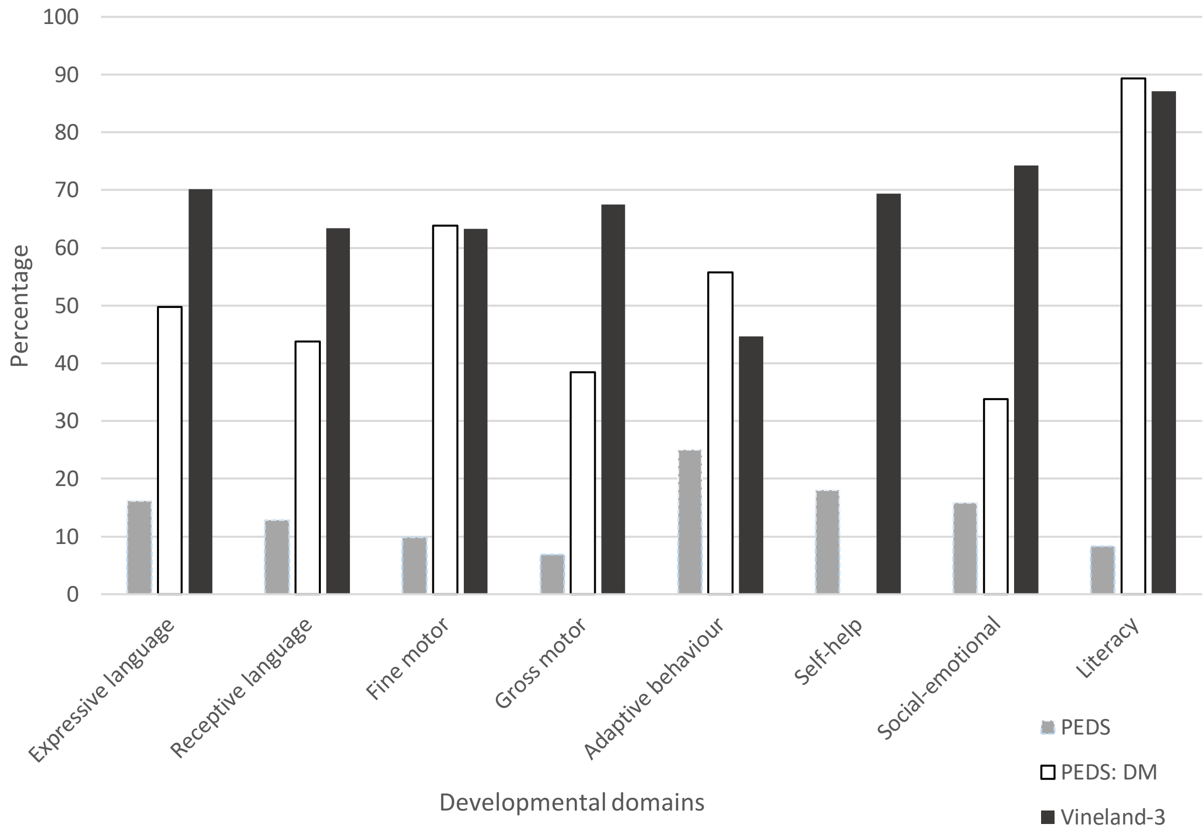

Figure 2. Comparison of domain-specific concerns/delays (according to prescribed criteria) between mHealth PEDS tools and Vineland-3

* Self-help domain not evaluated by PEDS: DM

Of the total population (n=276), 38 (13.8%) participants were falsely identified with a possible developmental delay when using the mHealth PEDS tools (false positives). These children failed the mHealth PEDS tools, but passed diagnostic assessment using the Vineland-3 (Table 2). According to the PEDS, most children failed on adaptive behavioural skills (39.5%; n=15) and expressive language skills (36.8%; n=14). Adaptive behaviour (65.8%; n=25), fine motor (57.9%; n=22) and expressive language abilities (47.4%; n=18) were failed most on the PEDS: DM. Most of the children (68.4%; n=26) had three or more concerns identified by the PEDS: DM, with 28 children (73.7%) failing the PEDS with Path A to C. Within the false positive group, there was a statistically significant difference between child age and caregiver concerns regarding expressive language (*t*(36)=2.48, *M = 10.0,* 95% CI 1.83, 18.22), adaptive behaviour (*t*(36)= 3.32, *M* = 12.1, 95% CI 4.68, 19.52) and literacy (*t*(21)=2.87, *M* = 11.2, 95% CI 3.07, 19.25) when using the PEDS: DM (Table 2). Using the PEDS, gross motor (*t*(36)=1.15, *M* = 11.1, 95% CI 8.39, 30.55) and social-emotional (*t*(36)=3.23, *M* = 17.0, 95% CI 6.33, 27.71) domains were significantly different across child age (Table 2).

Table 2. Estimated variance between developmental screening outcomes and age within false positive group using Independent samples T-test and point estimates (M) with 95% Confidence Intervals

Developmental domain		**Concerns n=38 (%)**	**Age variance *t***	**Mean difference (95% CI)**
Global	PEDS	5 (13.2)	1.76	11.2 (-1.77, 24.21)
Receptive language	PEDS	8 (21.1)	.50	2.7 (-8.13, 13.51)
	PEDS:DM	13 (34.2)	0.06	0.3 (-9.62, 9.04)
Expressive language	PEDS	14 (36.8)	.88	4.0 (-5.12, 13.04)
	PEDS:DM	18 (47.4)	2.48	10.0 (1.83, 18.22)
Fine motor	PEDS	3 (7.9)	1.92	6.0 (-1.05, 12.99)
	PEDS:DM	22 (57.9)	0.15	0.7 (-8.32, 9.61)
Gross motor	PEDS	2 (5.3)	1.15	11.1 (8.39, 30.55)
	PEDS:DM	5 (13.2)	0.41	1.3 (-5.29, 7.90)
Adaptive behaviour	PEDS	15 (39.5)	1.35	5.9 (-2.94, 14.73)
	PEDS:DM	25 (65.8)	3.32	12.1 (4.68, 19.52)
Social-emotional	PEDS	6 (15.8)	3.23	17.0 (6.33, 27.71)
	PEDS:DM	12 (31.6)	1.35	6.9 (-17.29, 3.57)
Self-help	PEDS	11 (28.9)	0.44	2.1 (-7.63, 11.85)
School	PEDS	3 (7.9)	0.52	4.2 (-20.52-12.20)
Numeracy*	PEDS:DM	12 (42.9)	1.63	7.6 (-17.22, 1.97)

Literacy**	PEDS:DM	19 (82.6)	2.87	11.2 (3.07, 19.25)
General	PEDS	10 (26.3)	1.24	6.4 (-4.14, 16.92)

* Numeracy total: n=28; only children between the ages of 3year 3 months and older than 4 years 1 month.

** Literacy total: n=23; only children older than 3years 8 months

Convergent validity was determined by comparing developmental domain outcomes of the PEDS and PEDS: DM to those of the Vineland-3 (Table 3). When comparing Vineland-3 domain-specific developmental outcomes to that of the PEDS: DM, a moderately positive association was found between adaptive behaviour (η(276) =.476, 95% CI .758, .775) and literacy skills (η(276) = .443, 95% CI .004, .007). A moderately positive association (η(276) =.587, 95% CI .049, .057) was also found between adaptive behaviour skills when comparing PEDS and Vineland-3 results.

Table 3. Convergent validity using ETA correlation ratio with 95% CI of PEDS and PEDS: DM compared to Vineland-3 (n=276)

Developmental domain	PEDS		PEDS:DM	
	ETA Correlation	**95% CI**	**ETA Correlation**	**95% CI**
Receptive language	.337	.559, .579	.291	.034, .041
Expressive language	.399	.576, .959	.220	.701, .725
Fine motor	.258	.183, .198	.331	.536, .556
Gross motor	.361	.643, .662	.349	.022, .028
Adaptive behaviour	.587	.049, .057	.476	.758, .775
Social-emotional	.374	.743, .760	.286	.246, .264
Self-help	.273	.449, .469	N/A*	N/A*
Literacy	.270	.004, .007	.443	.004, .007

* Self-help domain not evaluated by PEDS: DM

Discussion

This study validated an updated version of the mHealth PEDS tools for the screening of children, up to 83 months of age, who are at risk of developmental delays. Outcomes of the mHealth PEDS tools screening was significantly associated with the reference standard, the Vineland-3 (Table 1). Sensitivity (92.6%) was found to be higher than specificity (22.5%) when employing the prescribed referral criteria of the mHealth PEDS tools. It is imperative that developmental screening tools have high sensitivity (Plante and Vance, 1994). PPV was 84.0% indicating that a small percentage of children with developmental concerns would be missed. Another study found similar sensitivity and PPV scores within a high risk population, with the use of the mHealth PEDS tools (van der Linde et al., 2016).

Specificity remained low, indicating that few children who passed the mHealth PEDS tools also had no developmental delay according to the Vineland-3. Low specificity (22.5%), however, indicates that there will likely be a high rate of over-referrals. Usually, a specificity rate of 70% or higher is desired, since normal development is more prevalent than atypical development (Glascoe, 2013). A previous study using the mHealth PEDS tools within a multilingual community reported a specificity of 73% (van der Linde et al., 2016). Nevertheless, a lower specificity can be expected within this population, as it is a high risk, vulnerable population with exposure to at least three biological and environmental risks (n=272; 98.6% of children in current study) such as caregiver unemployment, single caregiver-headed households, low education level and multiple language exposure. Therefore, despite the lowered specificity, the mHealth PEDS tools have been shown to be effective within a low SES context such as South Africa as it still serves to identify children at risk of developmental delays and contributes to caregiver knowledge and awareness regarding early childhood development.

A recent study explored adapted referral criteria of the mHealth PEDS tools for the South African context (Maleka et al., 2019). When the various adapted referral criteria were used, sensitivity decreased (86.6% and 74.4%) and specificity increased (28.6% and 46.4%). Therefore, referral criteria 2 may be a more appropriate criteria to implement within the South African context, as sensitivity is high and there is a decrease in over-referrals. When referral criteria 2 is applied, the referral rate of the mHealth PEDS tools lowered to 70.3% (196/279).

It should also be considered that the Vineland-3, the reference standard used in this study, is the most recent edition of this tool and has not been standardised for the South African context. Previous versions, however, have been shown to be effective within the South African context and it has been recommended for use in this context as a result (Allen et al., 2014; Watermeyer et al., 2006). The Vineland-3 and mHealth PEDS tools both rely on parent-report (Glascoe, 2013).

Factors that may influence low specificity of the mHealth PEDS tools include a group of children who failed the mHealth PEDS tools, but passed the Vineland-3 diagnostic assessment (n= 38; 13.8%; false positives). This may be attributed to the application of the original US cut-off scores (delay vs no delay) on this vulnerable population (Sparrow et al., 2016). Applying cut-off scores of a specific population to a culturally and linguistically different population may result in higher false positives (Kiing et al., 2012).

Adaptive behaviour, which resulted in higher false positive rates across the mHealth PEDS tools should also be explored. Previous studies also reported higher referral rates within this specific domain (Maleka et al., 2019; Marshall et al., 2016). This may be due to caregivers interpreting normal behaviour differently or comparing their child's behaviour to other children or siblings (Marshall et al., 2016). Cultural norms and views related to social communication and acceptable behaviour differ across cultures (Soto et al., 2015; Rudra et al., 2014). Behaviour is often viewed by caregivers as what is expected and accepted within their respective communities. The type of behaviour that will maintain a respectful life within the family and community varies within and across various cultures (Balton et al., 2019). A previous study demonstrated that up to 43% of caregivers are concerned about their child's behaviour, whereas no problems/delays are identified during a formal developmental assessment (Glascoe, 2013).

If caregiver concerns that specify only high developmental risk are analysed, false positives may be reduced, but this may also reduce sensitivity of the tool (Woolfenden et al., 2014). It is therefore recommended that children who are identified by the mHealth PEDS tools as low to moderate risk first undergo a rescreen before referrals for diagnostic assessment are made (Restall and Borton, 2010; Limbos and Joyce, 2011).

False positives are preferred over false negatives in school-based screening programmes (Skarzyński and Piotrowska, 2012). The same may apply to developmental screening, as the benefits of detecting developmental delays outweigh over-referrals in children. Conducting developmental screening relying on caregiver-report within the preschool setting may also increase caregiver involvement; not only in terms of child development but also within the school environment.

Convergent validity was used to determine how the mHealth PEDS tools outcomes correlates with that of the Vineland-3 (Boateng et al., 2018). Convergent validity was found to be fair to moderate (.220 - .587) across all domains. Other validity studies on the PEDS found similar correlations (Glascoe, 2013). Variance in validity occur as caregivers do not necessarily understand the relationship between their concerns and the measurable weaknesses in developmental domains (Glascoe, 2013). Even though validity is not perfect, the mHealth PEDS tools are still considered a valid and reliable tool to implement across various countries and socio-economic settings (Vameghi et al., 2015; Limbos and Joyce, 2011; Huntington et al., 2016).

Implications for practice

Validated tools such as the mHealth PEDS tools would prove valuable when implemented within the preschool context. Further investigations to ensure their appropriateness for various context in terms of language variance, phrasing and referral criteria are required. Although this research project involved conducting screening amongst vulnerable, high-risk children, the value of developmental screening and surveillance cannot be underestimated. Developmental surveillance through conducting regular screenings in the same context, i.e. a preschool, may provide important information on children's developmental profiles over a longitudinal period. This will ensure that appropriate school-based intervention recommendations and programmes can be developed to readily address concerns as they arise.

Conclusion

Although high sensitivity and lower specificity on the mHealth PEDS tools were found, it may still be valuable for preschool developmental surveillance of children within low SES settings. Adapted referral criteria may, however, be more appropriate for implementation within these settings. When adapted referral criteria are applied, less children will be considered as high-risk as when using the US standardised criteria. Convergent validity was found to be moderate. A small proportion of false positives were evident and may be minimised by rescreening using the same mHealth PEDS tools, before referral is made to healthcare professionals.

Conflicts of interest

There are no conflicts of interest to report.

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