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A COMPARISON OF THE MOTOR SKILLS OF YOUNG PEOPLE IN A YOUTH DETENTION CENTRE WITH DIAGNOSED FETAL ALCOHOL SPECTRUM DISORDER, PRENATAL ALCOHOL EXPOSURE, AND A REFERENCE POPULATION

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ABSTRACT

Background

Motor skill difficulties are commonly experienced by people prenatally exposed to alcohol and are included in the diagnostic criteria for Fetal Alcohol Spectrum Disorder (FASD). Impaired motor skills are correlated with lower school completion rates, reduced recreational participation, and mental health and social issues. Visual-motor integration is a core skill for academic skills such as handwriting.

Objective

To assess and characterize motor performance in young people in an Australian youth detention centre and explore the relationship between motor skills, FASD and Prenatal Alcohol Exposure (PAE).

Materials and Methods

Participants completed the Movement Assessment Battery for Children-2 (MABC-2), Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI) including its associated subtests, and a handwriting screen.

Results

Ninety-nine young people (n=47 PAE; n=36 FASD) with a mean age of 16 years were assessed. There was an association between a FASD diagnosis and lower scores on the VMI (p=0.005). Participants with FASD and PAE had higher impairment levels on the VMI compared to the No-PAE group. Mean MABC-2 scores were within age expected levels across all groups. More fine motor skill difficulties were observed compared to gross motor skill difficulties. Handwriting skills were below age expected levels in 84% of participants. Those in the PAE and FASD groups had more difficulty with letter formations and spatial awareness.

Conclusions

VMI and handwriting skills were often impaired in this population. Lower VMI scores were more prevalent in participants diagnosed with FASD, and therefore should be routinely assessed as part of a diagnostic assessment. Assessment of fine and gross motor skills enabled recommendations for intervention support that address deficits and build upon strengths. Further research is needed to confirm these results using larger populations, and to investigate possible confounding factors associated with high VMI and handwriting difficulties in this population.

Keywords: *Fetal alcohol spectrum disorder, motor skills, child development; adolescent, prisoners*

Fetal Alcohol Spectrum Disorder (FASD) is a developmental disability that occurs as a result of alcohol exposure in utero.[1] FASD presentation is variable between people, but diagnosis in Australia is based on assessment for 3 distinct facial features; and impairments across 3 or more domains of neurocognitive functioning including brain structure/neurology, motor skills, cognition, language, academic achievement, memory, attention, executive functions, affect regulation, adaptive behaviour, and social skills or social communication.[2] The Australian Guide to the Diagnosis of FASD, like the Canadian guideline,[3] refers to 'FASD' as a singular diagnostic term with 2 subcategories; FASD with 3 facial features, and FASD with less than 3 facial features.[2]

A recently published systematic review and meta-analysis estimated that the global prevalence of FASD in the general population was 7.7 per 1000 people.[4] A recent systematic literature review found a disproportionally higher prevalence of FASD among young people in criminal justice systems, ranging from 10 to 22% across 3 studies.[5] A study in a youth detention centre in Western Australia, from which this study population is drawn, reported the prevalence of FASD to be 36%.[6] Popova et al.[7] estimated that people with FASD were 19 times more likely to be incarcerated over their lifetime. Other reported secondary outcomes for those with FASD include mental health diagnoses, lower school completion rates, drug and alcohol misuse, dependence on support with daily living skills, challenges with ongoing employment, and poor protective behaviours.[8,9]

Motor skills is one domain of brain function routinely assessed as part of a FASD diagnostic investigation.[2] Motor skills are defined as a combination of fine motor, gross motor and visual-motor integration (VMI). Fine motor skills include manipulating small objects through the use of precision, dexterity, and coordination.[10] Gross motor skills include large muscle groups working to create whole body movements such as hopping, jumping and running.[10] VMI skills involve the left and right brain hemispheres communicating, to take in and evaluate visual information, and plan and perform a motor output in response.[11] Neurological damage caused by Prenatal Alcohol Exposure (PAE) to the corpus callosum, cerebellum, motor cortex, and the peripheral nervous system is thought to have an effect on motor skill development including fine motor, balance and visual-motor integration.[12,13,14,15]

Research into Developmental Coordination Disorder suggests that motor skill difficulties may reduce or change throughout the lifetime due to structural changes at the neurological and musculoskeletal level, use of compensatory strategies (e.g., computer instead of handwriting), mastery after persistent practice, and avoidance of challenging tasks (e.g., team sports).[16] It is unknown whether potential changes would be similar for those with motor impairments that are a result of PAE. Some research indicated that motor impairments related to PAE became more pronounced with the child's age;[17,18] while others found that motor impairments observed in early childhood diminished in the adolescent years.[19]

Previous research into the motor skills among older populations diagnosed with FASD has included a longitudinal study that followed 402 people with PAE into adulthood. Researchers found that when participants reached 25 years of age, only those who were documented to be exposed to high levels of alcohol, and had multiple neurocognitive impairments, had persistent motor deficits.[17] The adults with a FASD diagnosis had poorer balance compared to their younger selves, indicating that balance may be an ongoing concern into adulthood.[17] In other studies, VMI skill deficits appeared to persist or worsen as children became older.[18,19,20] In terms of fine motor skills, Tamana et al.[18] reported that those in an adolescent age group performed more poorly than younger participants on hand strength, fine motor speed and coordination assessments. Other studies have not found significant differences between the fine motor skills of adolescent participants diagnosed with FASD compared to matched control groups.[20,21,22] Some of these previous studies used motor assessments not commonly used in clinical practice, and with weak psychometric properties; therefore, they may not provide an accurate representation of motor difficulties in an adolescent population with PAE or FASD.[23]

No studies were found that documented the handwriting skills of adolescents with FASD or PAE. Two studies reported higher levels of handwriting difficulties in younger children diagnosed with FASD or who had PAE compared with typically developing children.[24,25]

In addition to PAE, a systematic review found that motor difficulties were linked with other causes including hereditary factors, prenatal cannabis exposure, and perinatal complications.[26] There is also evidence that childhood trauma impacts on a child's health, development and neurocognitive outcomes including motor skills.[27,28] A recent review article found that childhood trauma coupled with exposure to alcohol in utero may have a compounding effect on neurological outcomes.[29]

There is limited research into the motor deficits of young people residing in detention settings. One study reported the prevalence of dyspraxia to be as high as 61% in a sample of 67 youth offenders.[30] However, this figure was likely inflated due to results obtained using now outdated and simple screening testing tools.

Motor impairments have been associated with psychosocial factors including poorer social skills, lower participation and involvement in sport and recreation, reduced employment, higher anxiety, and reduced self-worth.[16] The mixed and limited information available about the motor skill difficulties experienced by adolescents prenatally exposed to alcohol indicates a need for more detailed research. This is the first study to assess functional motor skills using standardized assessments in a correctional setting.

The aim of the current study was to investigate the fine and gross motor, and VMI skills of young people living in a youth detention centre and to determine if these skills were comparable between those with PAE, those without PAE, those with a FASD diagnosis, and those without a diagnosis.

Results from this study could be used to inform whether motor impairments should be routinely assessed as part of a FASD diagnostic assessment in adolescents, and to improve the management of young people with a FASD diagnosis through targeted interventions that use identified strengths and areas of difficulty to support functional outcomes.

METHODS

Participants

This paper reports the motor skill assessment data from the Banksia Hill Detention Centre FASD Prevalence Study conducted between May 2015 and December 2016, in Perth, Western Australia.[6] Banksia Hill Detention Centre is the only youth detention centre in Western Australia, with young people from metropolitan, regional and remote areas of the state being detained or sentenced there. Study participation was voluntary, with eligibility open to sentenced young people aged between 10 years and 17 years and 11 months of age. Recruitment was conducted by a research officer. Written parental consent was obtained after a young person had voluntarily agreed to participate. The research officer completed interviews with the young people and their caregivers to gather relevant background information; including information about PAE, school attendance, and health and development history. This information was disclosed to the clinical team at the conclusion of the assessments to minimize bias. Further details about recruitment and participation can be found in the Banksia Hill FASD Study prevalence paper [6] and methodology paper.[31]

Ethics approval for the FASD prevalence study was granted by the Western Australian Aboriginal Health Ethics Committee (approval number 582) and the University of Western Australia (approval number RA/4/1/7116). Research approval was granted by the former Department of Corrective Services Research and Evaluation Committee (DCS; project ID 335) and the Department of Child Protection and Family Support also gave approval for the research to include young people in their care (approval number 2015/8981). All research was conducted within the principles of the Declaration of Helsinki.[32]

Instruments

Based on population data from the detention centre, it was known prior to the study that approximately 75% of the study participants would be of Aboriginal Australian background. There are no motor assessments normed with Aboriginal Australian populations, so considerations were needed to ensure the assessments chosen would be as culturally appropriate as possible. This included reviewing previous studies conducted in similar populations. All motor assessments were administered and scored by a registered occupational therapist. Assessments included the Movement Assessment Battery for Children (MABC-2),[33] the Beery-Buktenica Developmental Test of Visual-Motor

TABLE 1 Tools Used to Assess Motor Function

Instrument, Developers, year	Age range	Components	Scores/descriptors	Psychometrics
Movement Assessment Battery for Children 2nd edition (MABC-2), Age Band 3 Henderson, Sugden, & Barnett, 2007[33]	3–16 years 11 months old	<u>Subtests:</u> Fine motor coordination: pegboard (dominant and non-dominant hands), construction, and pencil control task. Aiming and catching: Throwing and catching a tennis ball against a wall (one hand at a time), and aiming and throwing at a target on a wall. Balance skills: balance on a beam, walking backwards along a line, and hopping.	Subtest and Total Movement Score. Standard scores, percentiles, and interpretation using a traffic light system with <5th percentile = 'red zone' (significant movement difficulty); 5th–15th percentile = 'amber zone' (at risk of a movement difficulty), and >15th percentile = 'green zone' (no movement difficulty detected) [33](p. 176).	Standardized, and norm-referenced. Internal reliability ($\alpha = 0.90$) and test-retest reliability for the total score are high (ICC = 0.97) [46] The assumption was made that the tool would be sensitive enough to detect motor impairment in participants up to 17 years and 11 months old
Beery Buktenica Developmental Test of Visual-Motor Integration 6th edition[34]	2–99 years old	The Beery Buktenica Developmental Test of Visual-Motor Integration (VMI) <u>Subtests:</u> Visual Perception (VP) Motor Coordination (MC).	Standard scores, percentiles and descriptive categories based on standard scores: < 70 = 'very low', 70–79 = 'low', 80–89 = 'below average', 90–109 = 'average', 110–119 = 'above average', 120–129 = 'high', and >129 = 'very high'[34] (p. 94).	Standardized, and norm-referenced. Strong validity, including concurrent validity (r =0.52 0.75 with 3 similar assessments) (Beery & Beery, 2010) Sound content reliability, test-retest reliability, and inter-rater reliability.[34]
Handwriting screen	N/A	Free-writing and copying task.	Observations recorded: handwriting legibility, pencil grasp, handwriting speed, fatigue, pen pressure, sizing and spacing. Results based on observations and clinical judgment.	Non-standardized

Integration (VMI) and its associated Visual Perception (VP) and Motor Coordination (MC) subtests,[34] and a handwriting screen. These assessments are recommended in the Australian Guide to the Diagnosis of FASD.[2] See Table 1 for details of these assessments. The research officer categorized prenatal alcohol consumption using modified questions from the Alcohol Use Disorders Identification Test–Consumption (AUDIT-C). This is a standardized and validated measure to assess self-reported alcohol consumption during pregnancy from the birth mother, another proxy of the participant, or other documented evidence.[35] Based on AUDIT-C scores, prenatal alcohol consumption was categorized as 'no exposure', 'confirmed', and 'confirmed high risk'.

Procedure

The motor assessment took place in a room within the detention centre, and lasted for approximately one hour. If required or requested, a break was offered, which did not affect the standardization of the assessment tools. Whenever possible, assessment tasks were completed in the same order with all participants, alternating between tabletop and gross motor tasks.

The Australian Guide to the Diagnosis of FASD classifies motor skills as impaired if standardized assessment z-scores are ≤-2 Standard Deviations (SD) from the mean.[2] This study used the MABC-2 and the VMI scores to make this determination.

Data Analysis

Statistical analysis was completed using IBM SPSS Statistics for Windows version 24.0. Where data were found to be approximately normally distributed, motor assessment subtest standard scores were described using means, SDs, ranges and 95% Confidence Intervals (CI). Independent samples t-tests were used to examine differences between motor assessment scores among participants who were exposed to PAE (PAE group) and not exposed to PAE (No-PAE group), as well as those who were diagnosed with FASD (FASD group) and those not diagnosed with FASD (No-FASD group). Participants with unknown PAE were excluded from the PAE analysis, and the PAE group included those with confirmed and confirmed-high risk scores based on the AUDIT-C results. Cohen's d was completed to calculate the effect size, with 0.2 being considered a small effect size; 0.5 a medium effect size; and 0.8 a large effect size.[36]

The percentage of participants who reached the level of impairment (z-score ≤ -2SD) were calculated. In addition, a score below the 5th percentile for the Total Test Score of the MABC-2 indicates a "significant movement difficulty" (p. 176);[33] and the number of participants below this score in the MABC-2 Total Test Score and subtests was also calculated. The Chi-Square Test of Independence and Phi effect size (0.1 a small effect, 0.3 a medium effect and 0.5 a large effect) was used to examine the association between impairment, PAE and FASD diagnosis. An alpha of 0.05 was used for all analyses.

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RESULTS

A total of 99 young people participated in the FASD and motor assessment process. Two participants opted to discontinue and did not complete the motor assessment in full; however, the subtests that were completed were included in the subtest analysis.

Participant Characteristics

The participant characteristics are presented in Table 2. Participants were aged from 13 to 17 years old, with a mean age of 16 years. Approximately half of the participants came from metropolitan areas. Of the participants, 73 self-identified as being Aboriginal Australian.

An intelligence quotient score (IQ) score at or below 70 determined during neuropsychology testing was seen in 24% of all participants, and 42% of participants with FASD. Of the total participants, 47% were exposed to alcohol prenatally, with over half of those being in the 'confirmed high risk' category. PAE was unknown for 13 participants. All participants who met criteria for a FASD diagnosis (N=36) had less than 3 sentinel facial features. The published FASD prevalence study where participants in this current study are drawn from, reported no difference in demographic details of eligible participants who

TABLE 2 Participant Characteristics

		Total Group (N = 99)	No-FASD (N = 63)	FASD (N = 36)	P-value (a)
		n%	n%	n%	
Age (mean and range) *years*		16 (13, 17)	16 (13, 17)	15 (13, 17)	0.002
Gender	*Male*	92 (92.9)	58 (92.1)	34 (94.4)	0.7
Last geographical location	*Metropolitan*	50 (50.5)	41 (65.1)	9 (25.0)	0.0001
	Regional or Remote	49 (49.5)	22 (34.9)	27 (75.0)	
Ethnicity	*Australian Aboriginal*	73 (73.7)	39 (61.9)	34 (94.4)	0.0004
Responsible adult	*Parent*	62 (62.6)	43 (68.3)	19 (52.8)	0.2
	Other family guardian	24 (24.2)	12 (19.0)	12 (33.3)	
	Department of Child Protection	13 (13.1)	8 (12.7)	5 (13.9)	
Last school year completed	*Below Year 7*	10 (10.1)	4 (6.3)	6 (16.7)	0.98
	Year 8–9	49 (49.5)	32 (50.8)	17 (47.2)	
	Year 10–12	34 (34.3)	25 (39.7)	9 (25.0)	
	Unknown	6 (6.1)	2 (3.2)	4 (11.1)	
Handedness	*Right*	86 (86.9)	54 (85.7)	32 (88.9)	0.7
PAE	*None*	39 (39.4)	39 (61.9)	0 (0)	(b)
	Unknown	13 (13.1)	13 (20.6)	0 (0)	
	Confirmed	19 (19.2)	5 (7.9)	14 (38.9)	
	Confirmed- high risk	28 (28.3)	6 (9.5)	22 (61.1)	
Head injuries	*Difficulties consistent with*	40 (40.4)	23 (36.5)	17 (47.2)	0.3
Motor skill domain	Impaired (c)	29 (29.3)	11 (17.5)	18 (50.0)	0.0006
Intelligence quotient	*<= 70*	24 (24.2)	9 (14.3)	15 (41.7)	0.002

(a) p value = Pearson chi square; except for age which was calculated using a T-test
(b) not calculated as FASD group is dependent on PAE
(c) Based on FASD diagnostic guidelines of standardised scores below -2SD on testing of motor skills

participated compared with eligible participants whose consent was not obtained (n=41).[6]

Motor Assessment Results

The motor assessment results can be found in Tables 3 and 4, where the total sample, PAE group, and FASD group results are provided and compared. Impairment levels across the total sample and each group are presented and compared in Table 5. Two young people with FASD had motor skill domain impairment and only 2 other domains impaired, hence their diagnosis of FASD was dependent on the motor domain. All other young people with FASD and motor impairment had 3 or more other domains of impairment in addition.

FINE MOTOR SKILLS

In the whole sample and among groups based on PAE and FASD diagnosis, the mean MABC-2 Manual Dexterity standard scores were within the average range compared to normative data. The total group

TABLE 3 Comparison of Motor Skills Between Young People with and Without PAE; and with and without FASD

	Total Sample		PAE vs No-PAE		FASD vs No-FASD	
	Standard Score Mean (SD)	95% CI (DF, t)	Diff in means (95%CI)	p-value and Effect Size (Cohen's D)	Diff in means (95%CI)	p-value and Effect Size (Cohen's D)
MABC Subtest						
Manual Dexterity	7.9 (3.0)	7.4, 8.5 (DF=98, t=26.5)	−0.1 (−1.4, 1.3)	0.9, 0.02	0.6 (−0.6, 1.9)	0.3, 0.2
Aiming and Catching(a)	11.9 (2.2)	11.5, 12.4 (DF=97, t=53.4)	−1.0 (−1.9, −0.1)	0.04, 0.5	−0.4 (−1.3, 0.6)	0.4, 0.2
Balance(a)	9.1 (2.5)	8.6, 9.6 (DF=97, t=35.0)	0.6 (−0.6, 1.7)	0.3, 0.2	0.9 (−0.1, 2.0)	0.09, 0.4
Total Motor Score(a)	9.1 (2.5)	8.6, 9.6 (DF=97, t=35.8)	−0.2 (−1.4, 0.9)	0.7, 0.09	0.6 (−0.4, 1.7)	0.2, 0.2
Beery VMI Subtest						
Visual-Motor Integration	78.3 (13.7)	75.5, 81.0 (DF=98, t=56.9)	6.0 (−0.1, 12.0)	0.05, 0.4	7.9 (2.4, 13.4)	0.005, 0.6
Visual Perception	85.5 (13.2)	82.9, 88.1 (DF=98, t=64.7)	4.7 (−0.9, 10.4)	0.1, 0.4	4.7 (−0.7, 10.1)	0.09, 0.4
Motor Coordination	79.7 (11.9)	77.3, 82.0 (DF=98, t=66.9)	1.0 (−4.1, 6.1)	0.7, 0.08	3.0 (−2.0, 7.9)	0.2, 0.2

Handwriting (b)					
		PAE vs No-PAE		FASD vs No-FASD	
	n %	Chi Square (Pearson)	Effect size (Phi)	Chi Square (Pearson)	Effect size (Phi)
Overall handwriting below average	81 (84.0)	0.2	0.2	0.3	0.1
Difficulties with:					
Legibility	56 (57.7)	0.8	0.03	0.4	0.08
Speed	44 (45.4)	0.1	0.2	1	0.005
Letter Formations	29 (29.9)	0.002	0.3	0.003	0.3
Pencil Grasp	38 (39.2)	0.1	0.2	0.2	0.1
Pencil Pressure	17 (17.5)	0.8	0.04	0.5	0.06
Spatial Awareness	34 (35.1)	0.04	0.2	0.04	0.2
Literacy (c)	17 (17.5)	0.7	0.04	0.6	0.05
Other	13 (13.4)	0.8	0.03	0.8	0.02

TABLE 4 No-PAE/PAE and No-FASD/FASD Motor Assessment Results

	No-PAE (N= 39)		PAE (N= 47)		No-FASD (N= 63)		FASD (N= 36)	
	Standard Score Mean (SD)	**95% CI**	**Standard Score (Mean, SD)**	**95% CI**	**Standard Score (Mean, SD)**	**95% CI**	**Standard Score (Mean, SD)**	**95% CI**
MABC Subtest								
Manual Dexterity	7.9 (3.3)	6.8, 9.0	8.0 (2.9)	7.1, 8.8	8.2 (3.1)	7.4, 8.9	7.6 (2.9)	6.6, 8.5
Aiming and Catching (a)	11.1 (2.2)	10.4, 11.8	12.1 (2.0)	11.5, 12.7	11.8 (2.3)	11.2, 12.3	12.1 (2.1)	11.4, 12.9
Balance (a)	9.4 (2.5)	8.6, 10.2	8.8 (2.6)	8.1, 9.6	9.5 (2.4)	8.9, 10.1	8.5 (2.7)	7.6, 9.5
Total Motor Score(a)	8.9 (2.5)	8.1, 9.7	9.1 (2.7)	8.3, 9.9	9.4 (2.4)	8.8, 10.0	8.7 (2.7)	7.8, 9.7
Beery VMI								
VMI	81.1 (14.0)	76.6, 85.7	75.2 (14.0)	71.1, 79.3	81.1 (12.2)	78.1, 84.2	73.3 (14.9)	68.2, 78.3
Visual Perception	87.5 (12.0)	83.7, 91.4	82.8 (14.0)	78.7, 86.9	87.2 (12.1)	84.2, 90.3	82.5 (14.5)	77.6, 87.4
Motor Coordination	80.4 (11.8)	76.6, 84.2	79.4 (11.8)	76.0, 82.9	80.7 (11.8)	77.8, 83.7	77.8 (12.0)	73.7, 81.8
Handwriting (b)								
	n (%)		**n (%)**		**n (%)**		**n (%)**	
Overall handwriting below average	29 (74.4)		39 (86.7)		50 (80.6)		31 (88.6)	
Difficulties with:								
Legibility	23 (59.0)		25 (55.6)		34 (54.8)		22 (62.9)	
Speed	13 (33.3)		22 (48.9)		28 (45.2)		16 (45.7)	
Letter Formations	5 (12.8)		20 (44.4)		12 (19.4)		17 (48.6)	
Pencil Grasp	11 (28.2)		20 (44.4)		21 (33.9)		17 (48.6)	
Pencil Pressure	8 (20.5)		8 (17.8)		12 (19.4)		5 (14.3)	
Spatial Awareness	9 (23.1)		20 (44.4)		17 (27.4)		17 (48.6)	
Literacy(c)	5 (12.8)		7 (15.6)		10 (16.1)		7 (20.0)	
Other	6 (15.4)	-	6 (13.3)	-	8 (12.9)		5 (14.3)	

'No-FASD' group includes n = 13 young people with unknown PAE who are not included in the No-PAE, PAE groups.
Effect size (Cohen's D): 0.2 = 'small' effect size, 0.5 = 'medium' effect size and 0.8 = 'large' effect size.
Phi effect size:0.1 = 'small' effect, 0.3 = 'medium' effect and 0.5 = 'large' effect.
The Beery VMI, Visual Perception, and Motor Coordination standard scores have a mean = 100, SD = 15.
The Movement ABC subtests have a mean = 10, SD = 3
(a) Aiming and Catching, Balance, and Total Motor Score: missing data n = 1
(b) Handwriting: Missing data n = 2
(c) Literacy: difficulties with spelling and/or reading identified informally during the assessment.

TABLE 5 Impairment Levels in the Total Sample, No-PAE/PAE and No-FASD/FASD Groups

	Total Sample (N=99)	No-PAE (N=39)	PAE (N=47)	P-value	Effect size	No-FASD (N=63)	FASD (N=36)	P-value	Effect size
	n (%)	n (%)	n (%)			n (%)	n (%)		
MABC Subtest									
Manual Dexterity									
<-2SD	11 (11.1)	6 (15.4)	4 (8.5)	0.3	0.1	7 (11.1)	4 (11.1)	1	0
<5th%	21 (21.2)	8 (20.5)	12 (25.5)	0.6	0.06	10 (15.9)	11 (30.6)	0.09	0.2
Aiming and Catching (a)									
<-2SD	0	0	0	n/a	n/a	0	0	n/a	n/a
<5th%	0	0	0	n/a	n/a	0	0	n/a	n/a
Balance (a)									
<-2SD	1 (1)	0	1 (2.2)	0.4	0.1	0	1 (2.9)	0.2	0.1
<5th%	6 (6.1)	1 (2.6)	5 (10.9)	0.1	0.2	1 (1.6)	5 (14.3)	0.01	0.3
Total Motor Score (a)									
<-2SD	5 (5.1)	2 (5.1)	3 (6.5)	0.8	0.03	2 (3.2)	3 (8.6)	0.2	0.1
<5th%	8 (8.2)	4 (10.3)	4 (8.7)	0.8	0.03	4 (6.3)	4 (11.4)	0.4	0.09
Beery VMI									
VMI: <-2SD	24 (24.2)	8 (20.5)	14 (29.8)	0.3	0.1	11 (17.5)	13 (36.1)	0.04	0.2
Visual Perception: <-2SD	13 (13.1)	4 (10.3)	8 (17.0)	0.4	0.1	7 (11.1)	6 (16.7)	0.4	0.08
Motor Coordination: <-2SD	22 (22.2)	6 (15.4)	12 (25.5)	0.2	0.1	11 (17.5)	11 (30.6)	0.1	0.2

Effect size= Phi: .1 is considered a small effect, .3 a medium effect and .5 a large effect.
p-value = Pearson chi square
(a) Aiming and Catching, Balance, and Total Motor Score: Missing data n = 1

mean standard score was 7.9 (95% CI=7.4–8.5), which is at the lower end of the average range. The No-FASD and FASD groups had similar mean standard scores; as did the PAE and No-PAE groups. Eleven participants in the study scored within the impaired range (≤–2SD from the mean); however, no association was found between impairment rates and PAE or FASD. A significant movement difficulty (<=5th percentile) was seen in 21 study participants. This was more common in the FASD group, with 31% of those with a diagnosis reaching this level; as opposed to 16% of those without FASD. However, there was only a weak association between FASD and Manual Dexterity scores (p=0.09).

Handwriting

Difficulties with handwriting were common across all groups. In the total participant group, 84% of participants were below expected levels for their handwriting abilities. There was no evidence of an association between overall handwriting ability and PAE or FASD.

When specific handwriting skills were analyzed; difficulties recorded in the total participant group in order of prevalence were legibility (58%), handwriting speed (45%), pencil grasp (39%), spatial awareness (35%), letter formations (30%), and pencil pressure (18%). Other areas of concerns were noted in 13% of participants (e.g. pain, fatigue, limited detail, and hypermobility). Quadropod and cross thumb pen grasps were commonly noted. There was an association with medium effect size both in the PAE and FASD groups with letter formation, with 49% of participants in the FASD group, and 44% in the PAE group having recorded difficulties (p=0.002 PAE/No-PAE groups, and p=0.003 FASD/No-FASD groups). There was also an association with small effect size between spatial awareness and both the PAE and FASD groups; with 49% in the FASD group, and 44% in the PAE group having recorded difficulties (p=0.04 PAE/No-PAE groups, and p=0.04 FASD/No-FASD groups). Across other handwriting skill areas, the groups ap-peared to have similar abilities. See Figure 1 for handwriting samples.

Aiming and Catching

Within the total participant group, none of the participants scored below the impairment level of ≤ -2SD or ≤5th percentile for the MABC-2 Aiming and Catching subtest. The total study group mean standard score was 11.9, and scores in all groups based on PAE and FASD were within the age appropriate range compared to normative data. The PAE group (mean score=12.1) performed better than the No-PAE group (mean score=11.1) with a medium effect size (p=0.04). A diagnosis of FASD was not associated with Aiming and Catching scores in this participant group (p=0.4).

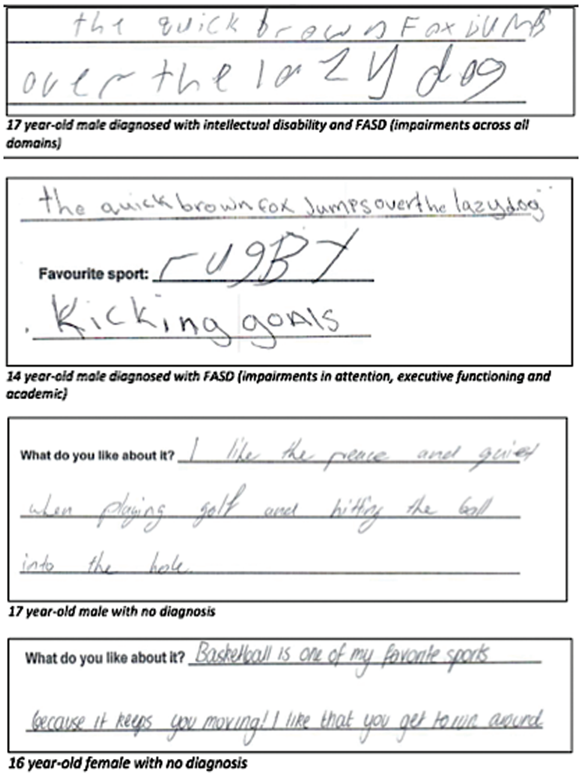
Balance

MABC-2 Balance mean standard scores in all groups were within the age expected range compared to normative data; the mean standard score for the total participant group was 9.1. One participant, who was in the FASD group, recorded a score below the impairment level. Although mean standard scores were lowest in the FASD and PAE groups, there was no evidence of a strong association between Balance scores and a FASD diagnosis or PAE in this study population (p=0.09 and 0.3 respectively). More participants recorded Balance scores in the significant movement difficulty range (≤5th percentile) in the FASD group (14% of participants) compared to the No-FASD group (2% of participants), with a small effect size (p=0.01).

Total Motor Score

The mean Total Motor score combines scores from the Manual Dexterity, Balance, and Aiming and Catching subtests of the MABC-2. The mean standard scores were similar between groups, and were within the age expected range compared to normative data. Five participants in the total participant group recorded scores in the impaired range for their overall motor score, 3 of these were from the FASD group. Eight participants in the total group had significant movement difficulty (≤5th percentile); 50% of these had a FASD diagnosis. The rates of impairment and significant movement difficulties were similar across all groups.

FIG 1 Handwriting Samples



Visual-Motor Integrations Skills

In the total participant group, the VMI mean standard score was 78.3 (95%CI=75.5, 81.0), and in the 'low' clinical range according to the test criteria (p. 94),[34] with 24 participants scoring in the impaired range (≤–2SD). The No-PAE group had a higher mean standard score (81.1) compared to the PAE group (75.2), with a small effect size (p=0.05). The percentage of participants in the impaired range was higher in the PAE group compared to the No-PAE group (30% and 20% respectively), but this was not significant (p=0.3).

There was an association between VMI scores and a FASD diagnosis, with a medium effect size. This was noted when comparing the No-FASD (73.3) and FASD (81.1) groups mean standard scores (p=0.005), and when comparing the proportion of those who scored in the impaired range (p=0.04). An impaired VMI score was observed in 36% of participants with FASD, compared to 18% of participants without a diagnosis. The mean standard score for the PAE and FASD group was in the 'low' clinical range, compared with the No-PAE and No-FASD groups in the 'below average' range.

The total participant group mean standard score was 85.5 for the VP subtest, which is in the 'below average' clinical range. Although the mean standard score in the FASD group (82.5) was lower than the No-FASD group (87.2); both of these scores were in the 'below average' clinical range, and there was only weak evidence of an association between FASD and VP scores (p=0.09).

The mean standard score for the MC subtest was in the 'low' clinical range for the total study population. The FASD group had the lowest mean standard score of 77.8 however, the scores were similar between all groups. There was weak evidence of higher rates of MC impairment for the FASD group compared to the No-FASD group (31% and 18% respectively; p=0.1).

DISCUSSION

A total of 99 young people participated in the motor assessments during this study, including 47 with PAE, and 36 diagnosed with FASD. VMI was the most common area of difficulty for this study group. In this study, the PAE and FASD groups had more participants with impaired VMI scores (30% and 36% respectively) compared with the No-PAE and No-FASD groups (21% and 18% respectively). This study indicates that having a diagnosis of FASD (with more neurocognitive impairments present) is associated with more prevalent impairment of VMI skills.

The VMI impairment levels in this study were higher than a population-based study, which assessed a younger population of 108 children in a remote Aboriginal community in Western Australia using the VMI.[37] These authors found that no child with a diagnosis of FASD, and only one child with PAE scored ≤-2SD on the VMI. The mean participant standard scores in the FASD and PAE groups were 84 and 87 respectively (both 'below average' clinical range).[37] The VMI scores in this current study are lower, with the FASD and PAE group means in the 'low' clinical range. This provides evidence to suggest that the gap in VMI skills may widen with increasing age, which was similarly reported by Tamana et al.[18]

Difficulties during the VMI were common in all participant groups. This may reflect the complex neurocognitive profiles such as executive functioning impairments reported in 78% of participants in this youth detention study population.[6] Executive functioning elements such as working memory and monitoring have been previously associated with VMI.[38] Other factors such as lived and intergenerational trauma, low school attendance levels, additional prenatal drug exposures, personal drug misuse, and head trauma histories, which were present for many young people in this study population, may also have impacted on the participant's performances. Due to the small sample sizes, we could not statistically control for these potential confounders.

Separate assessment of visual perception and MC components enabled identification of the main contributor leading to difficulties with VMI. In this study group, the MC subtest scores were lower when compared to the VP subtest. This may indicate that VMI differences are not due to visual perception in isolation; but likely due to the MC component of visual-motor integration, or the integration of both the visual perception and MC systems. However, the MC scores were not strongly associated with a FASD diagnosis or PAE. Similarly, there was no association between FASD or PAE and VP scores.

VMI skills are required for functional tasks such as dressing, catching a ball, driving and handwriting.[39] In this study the handwriting samples provided additional information used to inform the overall FASD diagnosis and complemented the conventional assessments of VMI. Handwriting was an area of concern seen in this study and although alternative technologies are more readily available in some settings, handwriting remains an important skill for academic success and employment options.[39] Previous studies that assessed handwriting skills in a younger study group using standardized measures, found handwriting was more commonly below expected levels among children diagnosed with FASD, with underlying concerns including pencil grasp, pencil pressure, legibility, and below average VMI skills highlighted.[24,25] Although in this current study, handwriting was a concern in 89% of those diagnosed with FASD, it was similarly difficult and challenging for those without FASD, with 81% experiencing difficulties. However, specific handwriting skills of letter formation and spatial awareness were more commonly recorded and associated with PAE or having a FASD diagnosis. These underlying skills may be affected by lower VMI scores which, in some cases, are associated with handwriting legibility.[40,41]

Another reported reason for handwriting difficulties is fine motor skills. In this study, mean MABC-2 Manual Dexterity subtest results were within the aver-age range for all groups regardless of PAE or FASD. However, significant fine movement difficulties were seen in 31% of participants with FASD. This shows that fine motor skills remain a clinical concern in this population. These results coincide with a previous study conducted in younger participants, where the mean scores of the Fine Motor Control subtest of the Bruininks–Oseretsky Test of Motor Proficiency—Second Edition (BOT-2) were lowest in the PAE and FASD groups.[42] The researchers reported that there was evidence that a FASD diagnosis was associated with a lower score in the Manual Coordination subtest of the BOT-2;[42] for which the current study had insufficient evidence to confirm in an adolescent population.

Although the sample size of this current study was small, there is indication that participants in the PAE group performed better than those in the No-PAE group for Aiming and Catching tasks. No participant scored in the impaired range for this task, which may reflect a strength in this participant group. Difficulties with balance tasks were rare. Only one participant, who was in the FASD group, scored below the impairment level on the MABC-2 Balance subtest. There is research that Aboriginal Australians engage in more regular physical activity, acquire motor skills at a younger age, and have strengths in motor skill acquisition.[43,44] These study participants, the majority of whom were Aboriginal, reported regular physical activity while they were residing in youth detention, and when in the community, including basketball, football, and resistance training. It may be that frequent physical activity levels have supported motor skill development in this participant group, as gross motor skills were rarely found to be a concern. This supports research about practice and learning effects leading to positive motor skill outcomes.[16]

While gross motor skills appeared to be a strength for participants in this study group with a high prevalence of FASD, a full gross motor assessment may be of benefit in helping the young person see they have strengths which can be utilized during ongoing management. Identifying strengths were reported to be highly valued by the young people in this study during a qualitative study capturing their experience with completing a FASD assessment.[45] This also highlights that movement-based interventions such as yoga, could be useful for use as a therapeutic tool for people with FASD, and should be further researched.

In this study 9% of participants with FASD had a MABC-2 Total Test Score below the impaired range. This result is similar to a previous study that reported 9.5% of younger children with FASD had a motor impairment based on the BOT-2 Total Motor Composite score.[42] In the current study, rates of impairment based on Manual Dexterity and VMI in isolation from a total motor score were higher, with 11% and 36% respectively in the FASD group. Given these results, it will be important to assess the subdomains of motor functioning and gather separate composite scores, rather than rely solely on a total motor score when determining a motor impairment during a FASD diagnosis assessment.

There are a number of limitations that need to be considered when interpreting the results of the current study. Due to the large proportion of Aboriginal Australians, and potential confounding factors within this novel study group, care needs to be taken in generalizing these conclusions to other populations with FASD, other youth detention populations, or a general adolescent population. Despite thorough research into the choice of assessments and using the VMI and MABC-2 with strong psychometric properties, the tools used have not been validated with Aboriginal Australians, so results need to be interpreted with caution. Although handwriting was informally assessed; reporting the results added an important functional element when discussing motor skills.

CONCLUSION

This is the first population-based study which details the motor profile of young people living in youth detention, using a comprehensive assessment battery. This study provides evidence for the routine use of assessing VMI skills when considering a FASD diagnosis for an adolescent in this cohort. A motor assessment that incorporates fine and gross motor functional skills should be used with all adolescents undergoing a FASD assessment. As difficulties with motor skills can have a large impact on a person's function, it is important that these skills are considered, and supports put in place if required. Given the relatively large proportion without motor skill impairment in this group of young people with high levels of other impairments,[6] conducting motor skill assessment can be invaluable for providing a balanced picture of their neurological profile, and provide a strength-based method for ongoing management for the young person.

VMI and handwriting skills were a common area of difficulty for the study population, even in those without FASD or PAE. The relationship between VMI, handwriting, and academic skills should be further researched, and investigation into whether early intervention prior to engagement with the justice system could improve academic outcomes and potentially be protective against contact with the justice system. Additionally, the use of movement-based interventions as a therapeutic tool for people with FASD and young people in detention should be further researched.

Although the focus of this study was on the motor skills of young people with PAE and those diagnosed with FASD, their incarceration in youth detention cannot be overlooked. Assessments for those young people in youth detention to enable better management, support, and rehabilitation back into the community is the first step to ensuring better life outcomes for these young people.

DISCLOSURE

All authors declare no conflict of interest.

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REFERENCES

1. Stratton K, Howe C, Battaglia F. Fetal alcohol syndrome: diagnosis, epidemiology, prevention, and treatment. Washington, WA: Institute of Medicine and National Academy Press; 1996.
2. Bower C, Elliott EJ, Zimmet M, et al. Australian guide to the diagnosis of foetal alcohol spectrum disorder: A summary. J Paediatr Child H 2017;53(10):1021–23. doi:10.1111/jpc.13625
3. Cook JL, Green CR, Lilley CM, et al. Fetal alcohol spectrum disorder: a guideline for diagnosis across the lifespan. CMAJ 2016;188:191–97. doi: 10.1503/cmaj.141593.
4. Lange S, Probst C, Gmel G, et al. Global prevalence of fetal alcohol spectrum disorder among children and youth: a systematic review and meta-analysis. JAMA Pediatr 2017;171(10):948–56. doi:10.1001/jamapediatrics.2017.1919
5. Hughes N, Clasby B, Chitsabesan P, Williams H. A systematic review of the prevalence of foetal alcohol syndrome disorders among young people in the criminal justice system. Cogent Psychol 2016;3(1). doi:1214213
6. Bower C, Watkins RE, Mutch RC, et al. Fetal alcohol spectrum disorder and youth justice: a prevalence study among young people sentenced to detention in Western Australia. BMJ Open 2018;8(2). doi:10.1136/bmjopen-2017-019605
7. Popova S, Lange S, Bekmuradov D, et al. Fetal Alcohol spectrum disorder prevalence estimates in correctional systems: a systematic literature review. C J Public Health 2011;102(5):336–40. doi: http://dx.doi.org/10.17269/cjph.102.2718
8. Clark E, Lutke J, Minnes P, et al. Secondary disabilities among adults with fetal alcohol spectrum disorder in British Columbia. J FAS Int 2004;2(13):1–12.
9. Streissguth A, Bookstein F, Barr H, et al. risk factors for adverse life outcomes in fetal alcohol syndrome and fetal alcohol effects. J Dev Behav Pediatr 2004;25(4):228–38. Available at: https://www.ncbi.nlm.nih.gov/pubmed/15308923
10. Jennett S. Churchill Livingstone Dictionary of Sport and Exercise Science and Medicine. Philladelphia: Elsevier Limited; 2008. Retrieved from http://medical-dictionary.thefreedictionary.com/motor+skills.
11. Schneck CM. Visual perception. In J. Case-Smith (Ed.), Occupational therapy for children (6 ed., pp. 373–403). St. Louis(MO): Elsevier Mosby; 2010.
12. Adnams CM, Kodituwakku PW, Hay A, et al. Patterns of cognitive-motor development in children with fetal alcohol syndrome from a community in South Africa [corrected] [published erratum appears in ALCOHOLISM 2001 Aug; 25(8):1187]. Alcohol Clin Exp Res 2001;25(4):557–62 556p.
13. Bookstein FL, Streissguth AP, Sampson PD, et al. Corpus callosum shape and neuropsychological deficits in adult males with heavy fetal alcohol exposure. Neuroimage 2002;15*(*1):233–51.
14. Roebuck TM, Simmons RW, Richardson C, et al. Neuromuscular responses to disturbance of balance in children with prenatal exposure to alcohol. Alcohol Clin Exp Res 1998;22(9):1992–97. Available at: https://www.ncbi.nlm.nih.gov/pubmed/9884143
15. Roebuck-Spencer TM, Mattson SN, Marion SD, et al. Bimanual coordination in alcohol-exposed children: Role of the corpus callosum. J Int Neuropsych Soc

2004;10(4):536–48. Available at: https://www.ncbi.nlm.nih.gov/pubmed/15327732
16. Hands B, Licari M, Piek J. A review of five tests to identify motor coordination difficulties in young adults. Res Dev Disabil 2015;41–42:40–51. doi:http://dx.doi.org/10.1016/j.ridd.2015.05.009
17. Connor PD, Sampson PD, Streissguth AP, et al. Effects of prenatal alcohol exposure on fine motor coordination and balance: A study of two adult samples. Neuropsychologia 2006;44(5):744–51. doi:http://dx.doi.org/10.1016/j.neuropsychologia.2005.07.016
18. Tamana S, Pei J, Massey D, et al. Neuropsychological Impairments and Age Related Differences – in Children and Adolescents with Fetal Alcohol Spectrum Disorders. J Popul Ther Clin Pharmacol 2014;21(2): e167–80.
19. Simmons RW, Thomas JD, Levy SS, Riley EP. Motor response programming and movement time in children with heavy prenatal alcohol exposure. Alcohol 2010;44(4):371–78. doi: 10.1016/j.alcohol.2010.02.013
20. Mattson SN, Riley EP, Gramling L, et al. Neuropsychological comparison of alcohol-exposed children with or without physical features of fetal alcohol syndrome. Neuropsychology 1998;12(1):146–53.
21. Vaurio L, Riley EP, Mattson SN. Neuropsychological Comparison of children with heavy prenatal alcohol exposure and an IQ-matched comparison group. J Int Neuropsych Soc 2011;17(3):463–73. doi:http://dx.doi.org/10.1017/S1355617711000063
22. Aragon AS, Kalberg WO, Buckley D, et al. Neuropsychological study of FASD in a sample of American Indian children: processing simple versus complex information. Alcohol Clin Exp Res 2008;32(12):2136–48. doi: 10.1111/j.1530-0277.2008.00802.x
23. Safe B, Joosten A, Giglia R. Assessing motor skills to inform a Fetal Alcohol Spectrum Disorder diagnosis focusing on persons older than 12 years: A systematic review of the literature. J Popul Ther Clin Pharmacol 2018;25(1):e25–e38. doi:10.22374/1710-6222.25.1.3
24. Doney R, Lucas BR, Jirikowic T, et al. Graphomotor skills in children with prenatal alcohol exposure and fetal alcohol spectrum disorder: A population-based study in remote Australia. Aust Occup Ther J 2016;64(1):68–78. doi:10.1111/1440-1630.12326
25. Duval-White CJ, Jirikowic T, Rios D, et al. Functional handwriting performance in school-age children with fetal alcohol spectrum disorders. Am J Occup Ther 2013;67(5):534–542 539p. doi:10.5014/ajot.2013.008243
26. Golding J, Emmett P, Iles-Caven Y, et al. A review of environmental contributions to childhood motor skills. J Child Neurol 2014;29(11):1531–47. doi:10.1177/0883073813507483
27. Norman RE, Byambaa M, De R, et al. The long-term health consequences of child physical abuse, emotional abuse, and neglect: a systematic review and meta-analysis. PLOS Med 2012;9(11): e1001349. doi:10.1371/journal.pmed.1001349
28. Rutter M, Rutter M. Developmental catch-up, and deficit, following adoption after severe global early privation. English and Romanian Adoptees (ERA) Study Team. J Child Psychol Psyc 1998;39(4):465. doi:10.1017/S0021963098002236
29. Price A, Cook PA, Norgate S, Mukherjee R. Prenatal alcohol exposure and traumatic childhood experiences: A systematic review. Neurosci Biobehav R 2017;80:89–98. doi:https://doi.org/10.1016/j.neubiorev.2017.05.018
30. Portwood M. Developmental Dyspraxia: Identification and Intervention (2 ed.). Oxon, UK: David Fulton Publishers; 1999.
31. Passmore HM, Giglia R, Watkins RE, et al. Study protocol for screening and diagnosis of fetal alcohol spectrum disorders (FASD) among young people sentenced to detention in Western Australia. BMJ Open 2016;6(6). doi:10.1136/bmjopen-2016-012184
32. World Medical Association. World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. JAMA 310 (20): 2191–94. 2013. doi:10.1001/jama.2013.281053
33. Henderson A, Sugden D, Barnett A. Movement Assessment Battery for Children (Movement ABC-2) (2nd ed.). London UK: The Psychological Corporation; 2007
34. Beery K, Beery N. The Beery-Buktenica Development Test of Visual-Motor Integration: administration, scoring and teaching manual (6th ed.). Minneapolis (MN): Pearson; 2010.
35. Bush K, Kivlahan DR, McDonell MB, et al. The audit alcohol consumption questions (audit-c): An effective brief screening test for problem drinking. Arch Intern Med 1998;158(16):1789–95. doi:10.1001/archinte.158.16.1789
36. Cohen J. Statistical Power Analysis for the Behavioral Sciences. Cambridge (MA): Academic Press; 1977.
37. Doney R, Lucas BR, Watkins RE, et al. Visual-motor integration, visual perception, and fine motor coordination in a population of children with high levels of

Fetal Alcohol Spectrum Disorder. Res Dev Disabil 2016;55:346–57. doi:http://dx.doi.org/10.1016/j.ridd.2016.05.009

38. Memisevic H, Sinanovic O. Executive functions as predictors of visual-motor integration in children with intellectual disability. Percept Motor Skill 2013;117(3):913–22. doi:10.2466/15.25.PMS.117x25z4
39. Tomchek SD, Schneck CM. Evaluation of handwriting. In A. Henderson & C. Pehoski (Eds.), Hand function in the child: foundations for remediation (pp. 293–318). St. Louis (MO): Mosby, Inc; 2006
40. Klein S, Guiltner V, Sollereder P, Cui Y. Relationships between fine-motor, visual-motor, and visual perception scores and handwriting legibility and speed. Phys Occup Ther Pedi 2011;31(1):103–14. doi:10.3109/01942638.2010.541753
41. Preminger F, Weiss PL, Weintraub N. Predicting occupational performance: handwriting versus keyboarding. Am J Occup Ther 2004;58(2):193–201. doi:10.5014/ajot.58.2.193
42. Lucas B, Doney R, Latimer J, et al. Impairment of motor skills in children with fetal alcohol spectrum disorders in remote Australia: The Lililwan Project. Drug Alcohol Rev 2016 doi:10.1111/dar.12375
43. Gwynn J, Hardy L, Wiggers J, et al. The validation of a self-report measure and physical activity of Australian Aboriginal and Torres Strait Islander and non-Indigenous rural children. Aus NZ J Publ Heal 2010;34:S57–S65. doi:10.1111/j.1753-6405.2010.00555.x
44. Taylor AJ, Taylor AJ. Coming, ready or not: Aboriginal children's transition to school in urban australia and the policy push. Int J Early Years Educ 2011;19(2):145–61. doi:10.1080/09669760.2011.602593
45. Hamilton S. A Prevalence Study of Fetal Alcohol Spectrum Disorder in Youth Detention in Western Australia. Poster presented at the 6th Annual National Health Medical Research Council Symposium on Research Translation, Brisbane; 2017.
46. Wuang Y-P, Su J-H, Su C-Y. Reliability and responsiveness of the Movement Assessment Battery for Children–Second Edition Test in children with developmental coordination disorder. Dev Med Child Neurol 2012;54(2):160–65. doi:10.1111/j.1469-8749.2011.04177.x