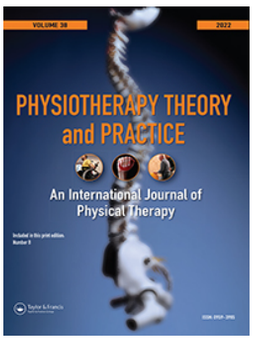

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The ability of the Ages and Stages Questionnaire (ASQ) to indicate motor difficulties in infants in primary care

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ABSTRACT

Introduction: Delayed achievement of motor milestones may be an early indicator of motor difficulties. Parent-reported questionnaires may serve as an efficient, low-cost screening to identify infants in need of further clinical assessment, and thus be a helpful tool in busy health care centers.
Purpose: To examine the ability of the Ages and Stages Questionnaire, second edition (ASQ-2) to indicate motor difficulties in infants using the Infant Motor Profile (IMP) as the reference standard.
Methods: A cross-sectional design was applied to examine the correlation between parent-reported data of the ASQ-2 and data from physiotherapist assessment using IMP. Included were 432 mainly low-risk infants aged 3–12 months from primary care.
Results: Overall, ASQ-2 gross and fine motor scores did not correlate well with the IMP total or domain scores. The ASQ-2 gross motor cut point (> 2SD below the mean), showed 34.3% sensitivity and 96.7% specificity using the 15th percentile from IMP performance domain as reference standard. The positive predictive value to indicate motor difficulties was 48%.
Conclusion: The motor domains of ASQ-2 have poor ability to identify infants with motor difficulties as indicated by their IMP scores in low-risk infants.

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Infant development; screening; Ages and Stages Questionnaire; discriminative ability; infant motor profile

Introduction

In Norway, multidisciplinary primary health care centers offer regular well-baby checkups for all children from birth to preschool age. The surveillance of motor development is a topic of interest for these checkups, with a low threshold for further assessment and referral to a physiotherapist. There is, however, no standard procedure for identifying infants requiring further assessments (Norwegian Directorate of Health, 2017). In busy health clinics, thorough motor assessments of all infants may be unnecessary, time-consuming, and costly. Hence, a simple screening tool with the ability to indicate motor difficulties could be helpful in this regard.

The Ages and Stages Questionnaire (ASQ) was developed in the 1980s as a parent-reported questionnaire to identify developmental delays in children aged 2–60 months (Velikonja et al., 2017). In addition to screening for gross and fine motor skills, ASQ also includes the domains of communication, problem-solving and socio-emotional skills. There are currently 3 editions available, and a 4th version is under revision. The second version of ASQ, ASQ-2 has been translated to Norwegian and is used both in routine follow-up in primary care and research (Markhus et al., 2018; Martinussen and Valla, 2013). The Norwegian version of ASQ-2 has demonstrated satisfactory reliability, but evidence for its validity is limited (Marks, Madsen Sjo, and Wilson, 2019; Martinussen and Valla, 2013).

To examine the ability of the ASQ-2 to indicate motor difficulties, it should be evaluated against a valid reference standard. However, which assessment tool should be used as the reference standard for motor difficulties in infants is ambiguous. When using the Bayley Scales of Infant and Toddler development, 3rd edition (Bayley-III) as a reference, the developers of ASQ-2 reported high mean sensitivity and specificity values across the age bands 4–48 months; sensitivity 75% and specificity 86% (Squires, LaWanda Potter, and Bricker, 1999). Similarly, high values were found by Gollenberg et al. (2010) using the Bayley III as a reference in low-risk infants (n = 53). However, a poor agreement between ASQ-3 and Bayley III was reported by Yue et al. (2019) in a mixed sample of infants aged 5–12 months. Also, in a study of children

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aged 1–36 months from a general population sample, the agreement of ASQ-3 and the Bayley-III was found to be relatively poor (Veldhuizen et al., 2015). In a systematic review Velikonja et al. (2017) found substantial variation in sensitivity values (33–83%) but only high specificity values (84–95%) for the ASQ-3. In a recent study Fauls, Thompson, and Johnston (2020) reported satisfactory values for both sensitivity and specificity of ASQ-3 gross motor score in children with concerns for motor delays. In the latter study, the < 10th centile on the Alberta Infant Motor Scale (AIMS) was used as a reference standard. In sum, the ability of ASQ to indicate motor difficulties in infants is inconsistent.

A promising alternative to the use of AIMS and Bayley-III as the reference standard might be the Infant Motor Profile (IMP) (Hadders-Algra and Heineman, 2021). IMP is a clinical, observational instrument that jointly considers both gross and fine motor milestones and quality of movement. The reliability and validity of the IMP have been examined and supported in prior research (Hecker et al., 2016; Heineman, Bos, and Hadders-Algra, 2011; Heineman et al., 2010, 2013; Tveten et al., 2020). In this study, we examined the ability of ASQ-2 to indicate motor difficulties in infants using the IMP as the reference standard.

Methods

This study has a cross-sectional design. It includes a sample of 432 individual infants enrolled during routine checkups in primary care in Norway in the period of 2016–2020. The infants were recruited from four different municipalities in both south-eastern and western parts of the country: Bamble (1 center); Porsgrunn, (1 center); Tønsberg (2 centers); and Bergen (17 centers). To obtain a sample typically seen in primary care, the criteria for eligibility were broad. All infants between 3–12 months of age, were eligible to participate in the study. Age was corrected for preterm birth for all infants with gestational age (GA) < 37 weeks. That is, if an infant was born 4 weeks preterm, the infant was assessed at its chronological age plus 4 weeks. Infants were excluded if the parents/ guardians did not speak Norwegian or English. The eligible infants and the parents/ guardians were invited to participate in the study by a health secretary or a public health nurse. Maternal and infant health demographics were retrieved from the Medical Birth Registry of Norway (2019). Informed written consent was obtained from the parents/guardians for each participating infant. The Regional Committee for Medical and Health Research Ethics approved the project (2016/566 REK Vest).

Assessments

The Ages and Stages Questionnaire, 2nd edition (ASQ-2)

Each domain in the ASQ-2 contains six questions which are scored by the parents on a three-point ordinal Likert scale ranging from "yes," "sometimes," to "not yet," based on what their child can do at the point of assessment. A score between 0 and 60 is obtained for each domain, with 60 as the optimal score. The questionnaire is easy to administer and takes about 10–20 minutes to complete (Squires, LaWanda Potter, and Bricker, 1999). Only scores from the motor domains were used in the present study.

Infant motor profile (IMP)

The IMP assessment is based on a 15–20 minute video recording of spontaneous movements, where the infant is observed whilst supine, prone, sitting, standing, walking, and during reaching and grasping depending on the age and functional level of the infant. In addition to a total score, each of the five domains, variation (25 items, two-point scales), adaptability (15 items, two-point scales), symmetry (10 items, three-point scales), fluency (7 items, two-point scales), and performance (23 items, two to seven-point scales), provides a score between 0 and 100, where 100 is the optimal score (Hadders-Algra and Heineman, 2021; Heineman, Bos, and Hadders-Algra, 2008). The time spent analyzing the videos depends on the video and the experience of the assessor but varies typically between 10–20 minutes in experienced scorers. Recently, norm references of IMP containing data from 1700 Dutch infants were published (Hadders-Algra and Heineman, 2021).

Procedure for ASQ-2 and IMP assessment

Most assessments were conducted at the primary health care centers, and in some cases at the infants' home, or Western Norway University of Applied Sciences, or a private physiotherapy clinic. The clinical assessments were performed according to the IMP procedure for all participants and conducted by the same pediatric physiotherapist (KMT). She had been trained earlier by the developers of the IMP and was blinded to the infant's medical history. Directly after the IMP assessment, the parents completed the ASQ-2 corresponding to their child's corrected age, blinded to the outcome of the IMP assessment. The physiotherapist was available for clarifications when the ASQ-2 was filled out. The scoring of IMP videos was conducted shortly after the assessment.

Statistical analysis

All data were analyzed using Stata IC version 16 (StataCorp, College Station, TX). Infant and maternal characteristics as well as ASQ-2 and IMP scores were quantified by descriptive statistics. The relationship between ASQ-2 domain scores and IMP total and domain scores was calculated using Spearman's correlation coefficient. The strength of correlation, r_s, was considered as very weak (0.00 to 0.20), weak (0.21 to 0.40), moderate (0.41 to 0.60), strong (0.61 to 0.80), and very strong (0.81 to 1.00) (Evans, 1996).

The 15th percentile scores of IMP from the published Dutch norms (Hadders-Algra and Heineman, 2021) were used as cut points to categorize infants with (< 15th percentile) or without (≥ 15th percentile) suspected motor difficulties. The ASQ-2 cut point for suspected motor difficulties is > 2 standard deviations (SD) below the mean (Squires, LaWanda Potter, and Bricker, 1999). To examine the ability of the ASQ-2 to indicate motor difficulties, we calculated sensitivity, specificity, and predictive values, using IMP as the reference standard.

Sensitivity is the probability of motor difficulties that are correctly identified by the ASQ-2, given that the infant showed motor difficulties by IMP (< 15th percentile scores). Specificity is the probability of no motor difficulties that are correctly identified by the ASQ-2, given that the infant did not show motor difficulties by the IMP (≥ 15th percentile scores). As recommended by the National Health and Medical Research Council (2002) sensitivity and specificity values ≥ 70% are considered acceptable. The positive predictive value (PPV) is the probability that the infants identified with motor difficulties by ASQ-2 truly have motor difficulties by IMP. The negative predictive value (NPV) is the probability that infants identified without motor difficulties by ASQ-2 truly do not have motor difficulties by IMP.

Results

Maternal and infant characteristics are provided in Table 1. Overall, 432 infants (224 boys, 208 girls) were included in the analyses. The mean age at assessment was 7.3 months. Nineteen infants were born at a GA < 37 weeks and the mean GA of all infants was 39.6 (SD 2.8) weeks. Most infants were born at or close to term, with average birth weight, and from healthy mothers with low-risk pregnancies and births (Table 1). Means (SD) of ASQ-2 and IMP scores for all infants are provided in Table 2.

Correlation between ASQ-2 and IMP scores

Overall, ASQ-2 gross and fine motor scores did not correlate well with the IMP total or domain scores (Table 3). An exception was for the correlation between ASQ-2 gross motor scores and the IMP performance, which was moderate to strong (r_s = 0.50–0.71) in the highest age groups (6 to 12 months), and varied between very weak (5 months), and weak to moderate (r_s = −0.00–0.46) at 3 and 4 months. Weaker and more variable correlations were found between the ASQ-2 fine motor scores and the IMP performance scores (Table 3). Due to the poor correlation of ASQ-2 with IMP total score and the other IMP domains, the remainder of the analyses focused only on the IMP performance as the reference standard.

The ability of the ASQ-2 to indicate motor difficulties using IMP performance as the reference standard

The number of infants in our sample with ASQ-2 gross and fine motor scores >2 SD below the mean was 25 and 20, respectively. The number of infants scoring below the 15th percentile for IMP performance based on Dutch norms was 35. The initial cross-tabulation analysis was performed for each age band, separately, and then for the two age groups; 3–6 months and 7–12 months (Supplemental Table 1). However, not all age bands included infants with motor scores below both the ASQ-2 and the IMP cut points. Hence, sensitivity, specificity, and predictive values are presented for the entire study sample (Table 4).

The sensitivity and specificity of the ASQ-2 gross motor domain to correctly indicate motor difficulties/no motor difficulties as indicated by the IMP performance domain was 34.3% and 96.7%, respectively. The corresponding PPV and NPV were 48% and 94.2%, respectively (Table 4). The sensitivity and specificity of the ASQ-2 fine motor domain to correctly indicate motor difficulties/no motor difficulties as indicated by the IMP performance was 5.7% and 95.5%, respectively. The corresponding PPV and NPV were 10% and 92%, respectively (Table 4). An additional analysis using the 5th percentile of IMP performance as the reference standard resulted in even poorer ability of the ASQ-2 gross and fine motor domains to indicate motor difficulties (results not shown).

Discussion

This study showed that the gross and fine motor domains of ASQ-2 had poor ability to indicate motor difficulties in infants as indicated by IMP. In most age

Table 1. Infant and maternal characteristics.

Continuous variables	N	Mean (SD), Min-Max
Infant corrected age at assessment (months)	432	7.3 (2.8), 3–12
Gestational age (weeks)	432	39.6 (1.5), 33–42
Birth weight (g)	432	3562 (527), 1540–5240
Apgar, 5 minutes	431	9.5 (0.99), 1–10
Maternal age (years)	432	31.3 (4.5), 21–45
Maternal pre-pregnancy BMI	399	24.3 (4.5), 16–44
Categorical variables	N	%
Prematurity GA <37 weeks, yes/no	19/413	4.4/94.6
Singleton/twin	424/8	98.1/1.9
Sex, boy/girl	224/208	51.8/48.2
Congenital malformations (heart disease, palate cleft)	6 (4/2)	1.4
Smoking status	23/351	6.1/93.9
Pre-pregnancy (yes/no)	10/356	2.7/97.3
During pregnancy (yes/no)	5/341	1.4/98.6
End of pregnancy (yes/no)		
Marital status	153	35.5
Married	266	61.5
Cohabitant	12 1	2.8
Single		0.2
Other		
Parity	201	46.5
0 (first born)	165	38.2
1	49	11.4
2	16	3.7
3	1	0.2
>3		
Preeclampsia	424/6/2	98.1/1.4/0.5
None/mild/severe		
Gestational diabetes (yes/no)	18/414	4.2/95.8
Maternal hypertension during pregnancy (yes/no)	10/422	2.3/97.7
Mode of delivery	338	78.2
SPV	48	11.1
IVD	32	7.4
CS, acute	14	3.3
CS, elective		

Body Mass Index (BMI), Spontaneous Vaginal Delivery (SPV), Instrumental Vaginal Delivery (forceps or vacuum) (IVD), Cesarean Section (CS)

bands, the ASQ-2 gross and fine motor domains had very weak to weak correlations with both the IMP total and most of the IMP domain scores. The ASQ-2 gross motor domain and IMP performance domain had, however, moderate to strong correlations in eight of the ten age bands. Therefore, in further analysis, the IMP performance domain was used as the reference standard.

Table 2. ASQ-2 and IMP total and domain scores for all infants, n = 432.

	Mean	SD	Min	Max
ASQ-2				
Gross motor	47.2	13.9	5	60
Fine motor	51.6	10.7	10	60
Communication	48.6	9.8	15	60
Personal/social skills	50.1	9.2	10	60
Problem solving	52.6	8.8	10	60
IMP				
Variation	94.2	5.7	69	100
Adaptability*	95.4	9.2	63	100
Fluency	96.8	6.9	63	100
Symmetry	99.6	1.8	90	100
Performance	71.7	14.9	35	96
Total IMP score	89.6	5.2	74	99

Standard Deviation (SD), Ages and Stages Questionnaire Second Edition (ASQ-2), Infant Motor Profile (IMP). * Adaptability is only calculated for infants > 6 months.

Only 12 infants were correctly identified with motor difficulties by the ASQ-2 gross motor domain. The same domain was, however, able to sort out a large proportion of infants with no motor difficulties. Accordingly, we found specificity, but not sensitivity, to be within acceptable levels (> 70%) as suggested by the National Health and Medical Research Council (2002). The ability of the ASQ-2 gross motor domain was found to be better than the ASQ-2 fine motor domain to indicate motor difficulties by IMP performance domain.

We found an overall fair correlation between the ASQ-2 gross motor scores and IMP performance domain scores. ASQ-2 gross motor and IMP performance domains both assess motor milestones, such as rolling, crawling, and walking, explaining why these domains showed the highest correlation. Further, both ASQ-2 fine motor and IMP performance domains assess fine motor milestones such as reaching, grasping, and object manipulation. The correlation between these two domains was, however, weak in most age bands. An explanation for the weak correlation could be that parents are uncertain how to evaluate the fine motor items included in the ASQ-2, like identifying specific types of grasps and handling of objects.

Table 3. Correlation between ASQ-2 gross- and fine motor scores and IMP total and domain scores by Spearman's rank correlation coefficient, rs.

	IMP					
ASQ-2	Total score	Performance	Variation	Adaptability	Symmetry	Fluency
3 months, n = 46	0.20	0.46*	−0.03	–	0.11	0.15
Gross motor, r_s	0.28	0.34*	0.09		0.20	0.05
Fine motor, r_s						
4 months, n = 40	0.43*	0.33*	0.34*	–	0.24	0.33*
Gross motor, r_s	0.49*	0.51*	0.35*		0.13	0.39*
Fine motor, r_s						
5 months, n = 46	0.05	0.00	0.05	–	0.07	0.01
Gross motor, r_s	0.14	0.17	0.22		−0.10	−0.11
Fine motor, r_s						
6 months, n = 45	0.22	0.63*	−0.02	–	0.26	−0.10
Gross motor, r_s	−0.07	0.21	−0.14		0.18	−0.11
Fine motor, r_s						
7 months, n = 50	−0.17	0.50*	−0.1	−0.47*	−0.14	−0.12
Gross motor, r_s	0.03	0.28	−0.01	0.00	−0.15	−0.05
Fine motor, r_s						
8 months, n = 46	0.40*	0.69*	−0.11	−0.02	−0.09	−0.05
Gross motor, r_s	0.11	0.28	−0.06	−0.05	−0.07	−0.03
Fine motor, r_s						
9 months, n = 43	0.36*	0.71*	0.09	0.16	0.08	−0.12
Gross motor, r_s	0.04	0.22	−0.17	0.10	−0.13	−0.14
Fine motor, r_s						
10 months, n = 36	0.49*	0.69*	0.35	0.39*	0.10	0.29
Gross motor, rs	0.33	0.54*	0.33	0.16	0.08	0.23
Fine motor, rs						
11 months, n = 42	0.49*	0.56*	0.27	0.18	0.00	−0.06
Gross motor, rs	0.33*	0.09	0.39	0.26	−0.08	0.05
Fine motor, rs						
12 months, n = 37	0.24	0.58*	0.26	0.06	0.12	−0.13
Gross motor, r_s	0.07	-0.10	0.24	0.05	0.16	−0.09
Fine motor, r_s						

Ages and Stages Questionnaire Second Edition(ASQ-2), Infant Motor Profile (IMP), * p = <0.05

Further analysis of the ASQ-2 and the remaining IMP domains (i.e. variation, adaptability, fluency, and symmetry) and IMP total score were not performed due to very weak to weak correlations in most age bands. From a clinical perspective, this is unfortunate, as these IMP domains add important, qualitative information about motor function. Hence, using parent reports on motor milestones alone may not be sufficient for indicating suspected motor difficulties. As the IMP assessment requires special competence of the assessor, it may be too comprehensive and costly to be used for regular well-baby checkups but should be considered when concerns for motor function are present, or in cases of repetitive low scores on ASQ-2 over time.

The positive predictive value of the ASQ-2 gross motor domain was 48%. What should be considered acceptable predictive values depends on the short and long-term burden of the healthcare system, the severity

Table 4. The ability of ASQ-2 gross and fine motor scores to reflect motor difficulties by IMP performance scores.

		IMP performance domain		
ASQ-2 motor function		Motor difficulties (<15th percentile)	No motor difficulties (≥15th percentile)	
Gross motor domain	Motor difficulties (>2SD below the mean)	True positive: 12	False positive:13	PPV% (CI%): 48 (27.8–68.7)
	No motor difficulties (≤2SD below the mean)	False negative: 23	True negative: 384	NPV% (CI%): 94.3 (91.6–96.4)
		Sensitivity% (CI%): 34.3 (19.1–52.2)	Specificity% (CI%): 96.7 (94.5–98.2)	
Fine motor domain	Motor difficulties (>2SD below the mean)	True positive: 2	False positive: 18	PPV% (CI%): 10.0 (1.2–31.7)
	No motor difficulties (≤2SD below the mean)	False negative 33	True negative: 379	NPV% (CI%): 92 (88.9–94.4)
		Sensitivity% (CI%): 5.7 (0.7–19.2)	Specificity% (CI%): 95.5 (92.9–97.3)	

Ages and Stages Questionnaire Second Edition (ASQ-2), Infant Motor Profile (IMP), Confidence Interval (CI), Positive Predictive Value (PPV), Negative Predictive Value (NPV)

of the condition, and the psychological effect on the client (Trevethan, 2017). The follow-up from a screening test could for instance result in a further assessment with the IMP followed by therapeutic guidance from a physiotherapist. It would not be stressful for the infants and can be performed quickly. However, primary health care is often constrained by available resources, and if a high proportion of children not requiring further assessment (false positives) are referred to physiotherapy, it may create challenges regarding capacity. We could thus not consider the PPV as acceptable in this study.

When comparing our results to those of previous studies, one must keep in mind the differences in sample characteristics, the ASQ edition, and the reference standard used. We recruited participants through primary care centers that conduct well-baby checkups, offered to all infants living in Norway (Norwegian Directorate of Health, 2019). Based on the maternal and infant demographics, our sample consisted of mainly low-risk infants. We found, not surprisingly, that the prevalence of suspected motor difficulties in our sample was low. Previous studies examining the validity of ASQ have included samples with different risk profiles for motor difficulties (Fauls, Thompson, and Johnston, 2020; Gollenberg et al., 2010; Squires, LaWanda Potter, and Bricker, 1999; Veldhuizen et al., 2015; Yue et al., 2019). As the predictive value strongly depends on the prevalence, the agreement between a screening test and a reference standard is usually better in samples containing a higher proportion of children with suspected motor difficulties, as was the case in the study by Fauls, Thompson, and Johnston (2020). Hence, we should therefore not take the predictive values observed in our sample as applying universally to samples at higher risk of motor difficulties.

Further, each new edition of ASQ has small changes including revised cut points. This will influence the agreement with a reference standard, as the sensitivity and specificity of a screening test are dependent on the cut point used. Finally, prior studies have utilized AIMS and Bayley-III as the reference standard (Fauls, Thompson, and Johnston, 2020; Gollenberg et al., 2010; Squires, LaWanda Potter, and Bricker, 1999; Veldhuizen et al., 2015; Velikonja et al., 2017; Yue et al., 2019). To our knowledge, this is the first study to validate ASQ-2 according to the IMP, and thus it adds to the current state of knowledge.

A strength of our study is the large sample of infants assessed by a trained pediatric physiotherapist that was blinded to the infant's medical history. Nevertheless, some limitations should be noted; we had no information of how many eligible parents declined to participate, thus we do not know if our study is representative of those initially eligible. In addition, although our inclusion criteria were broad, the characteristics of our sample limit our findings to mainly term-born, low-risk infants aged 3–12 months.

Conclusion

In a sample of mainly low-risk infants in primary care, we found that the motor domains of the ASQ-2 had poor ability to indicate motor difficulties in infants as indicated by their IMP performance scores.

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Disclosure statement

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