Assessment of specific characteristics of abnormal general movements: does it enhance the prediction of cerebral palsy?

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ABBREVIATIONS

AIMS	Alberta Infant Motor Scales
ATNR	Asymmetrical tonic neck reflex
IMP	Infant Motor Profile
MDI	Mental Developmental Index
PEDI	Pediatric Evaluation of Disability Inventory
VIP	Vroegtijdig Interventie Project
COPCA	Coping with and Caring for infants with special needs - a family centered programme
GMFCS	Groos Motor Function Classification System
TIP	Typical infant physiotherapy

AIM Abnormal general movements at around 3 months corrected age indicate a high risk of cerebral palsy (CP). We aimed to determine whether specific movement characteristics can improve the predictive power of definitely abnormal general movements.
METHOD Video recordings of 46 infants with definitely abnormal general movements at 9 to 13 weeks corrected age (20 males; 26 females; median gestational age 30wks; median birthweight 1200g) were analysed for the following characteristics: presence of fidgety, cramped synchronized, stiff, or jerky movements and asymmetrical tonic neck reflex pattern. Neurological condition (presence or absence of CP), gross motor development (Alberta Infant Motor Scales), quality of motor behaviour (Infant Motor Profile), functional mobility (Pediatric Evaluation of Disability Inventory), and Mental Developmental Index (Bayley Scales) were assessed at 18 months corrected age. Infants were excluded from participating in the study if they had severe congenital anomalies or if their caregivers had an insufficient knowledge of the Dutch language.
RESULTS Of the 46 assessed infants, 10 developed spastic CP (Gross Motor Function Classification System levels I to V; eight bilateral spastic CP, two unilateral spastic CP). The absence of fidgety movements and the presence of predominantly stiff movements were associated with CP (Fisher's exact test, p=0.018 and p=0.007 respectively) and lower Infant Motor Profile scores (Mann–Whitney U test, p=0.015 and p=0.022 respectively); stiff and predominantly stiff movements were associated with lower Alberta Infant Motor Scales scores (Mann–Whitney U test, p=0.01 and p=0.004 respectively). Cramped synchronized movements and the asymmetrical tonic neck reflex pattern were not related to outcome. None of the movement characteristics were associated with Pediatric Evaluation of Disability Inventory scores or the Mental Developmental Index.
INTERPRETATION The assessment of fidgety movements and movement stiffness may improve the predictive power of definitely abnormal general movements for developmental outcome. However, the presence of fidgety movements does not preclude the development of CP.

Assessing the quality of general movements is a non-invasive diagnostic tool used to predict cerebral palsy (CP) in young infants. General movements are spontaneous movements in which involve all body parts.[1] They are present from early fetal life and disappear around 4 months post term, when goal-directed motor behaviour emerges. The form of typical general movements changes several times as a result of developmental transformations of the nervous system. In the last phase, at around 2 to 4 months post term, general movements have a 'fidgety' character. Fidgety general movements occur irregularly all over the body and consist of a continuous stream of tiny elegant movements. During each phase, normal general movements are characterized by complexity, variation, and fluency.[1] General movements are considered as abnormal when their complexity and variation is reduced. Abnormal general movements are known to be associated with brain dysfunction and developmental disorders. Multiple studies have indicated that the presence of clearly abnormal general movements at 'fidgety age' indicates a high risk of CP.[1–5]

Currently, clearly abnormal general movements at 'fidgety age' are described in two slightly different ways. The Prechtl method[2] classifies general movements' quality at 'fidgety age' as abnormal if fidgety movements are absent or abnormal in nature. Abnormal is defined as the presence of fidgety movements with a moderately or greatly exaggerated amplitude, speed, and jerkiness.[3] The absence of fidgety movements predicts the development of CP substantially better than abnormal fidgety movements.[2] The definition of definitely abnormal general movements according to Hadders-Algra et al.[1] is based on the virtual absence of movement complexity and variation, whether or not fidgety movements are present. The presence of definitely abnormal general movements at 'fidgety age' is a good predictor of CP.

Other studies have indicated that the presence of cramped synchronized movements or the asymmetrical tonic neck

reflex (ATNR) pattern are early markers of CP.[6,7] Cramped synchronized movements are patterns in which all limb and trunk muscles contract and relax almost simultaneously. These movements appear to be rigid and lack the normal smooth and fluent character of general movements.[3] Cramped synchronized movements, which are consistently present during early infancy, are highly predictive of the development of CP.[6] The ATNR pattern consists of the extension of the limbs on the side to which the head is turned, with flexion of the contralateral limbs. Bruggink et al.[7] suggest that the presence of ATNR activity in infants with fidgety general movements is associated with an increased risk of developmental disorders.

The primary objective of the present study was to determine whether specific characteristics of definitely abnormal general movements, such as the occasional presence of fidgety movements or the presence of cramped synchronized movements, were related to developmental outcome at 18 months, in particular to CP. We hypothesized that the addition of extra markers of brain dysfunction to the mere notion of definitely abnormal general movements would enhance predictions of developmental outcome including the risk of CP. To this end, we used data collected in the Vroegtijdig Interventie Project [VIP] Holland, an early study on the effects of two types of intervention in infants at high risk of developmental disorders.

What this paper adds

- This paper contains a detailed documentation of the movement characteristics of infants with definitely abnormal general movements.
- The absence of fidgety movements and presence of predominantly stiff movements are associated with CP and low IMP scores.
- Stiff movements are associated with lower AIMS scores.
- The presence of fidgety movements does not preclude the development of CP.

Table I: Perinatal characteristics of participants (*n*=46) and non-participants (*n*=12)

Variable	*n*=46	*n*=12	*p* value
Sex			
Male	20	8	0.246[a]
Female	26	4	
Gestational age (wks)			
Median	30	29	0.156[b]
Range	25–40	25–36	
Preterm (GA <37wks)	43	12	1.00[c]
Birthweight (g)			
Median	1200	1230	0.585[b]
Range	585–4750	705–2085	
Twin	16	5	0.744[c]
Severe brain lesion (total)	6	0	0.581[c]
PVL grade 3–4	2	0	
PVHI	2	0	
Thalamus/ basal ganglia	2	0	
Apgar scores			
Below 7 after 5min	7	3	0.683[c]

[a]Chi-squared test; [b]Mann–Whitney *U* test; [c]Fisher's exact test.
GA, gestational age; SD, standard deviation; PVL, periventricular leukomalacia graded according to de Vries et al.,[8] PVHI, periventricular haemorrhagic infarction according to Volpe,[9] formerly classified as grade 4 intraventricular haemorrhage.

METHOD

Participants

The participants in this study were 46 infants who had participated in the VIP. Inclusion in the VIP was based on the presence of definitely abnormal general movements (according to Hadders-Algra et al.[1]) at the beginning of the 'fidgety' general movement phase. The infants had been admitted to the neonatal intensive care unit of the Beatrix Children's Hospital of the University Medical Centre Groningen between March 2003 and May 2005. Infants were selected for video recording if they were born at a gestational age of less than 32 weeks or if other risk factors (e.g. artificial ventilation, acquired intracranial pathology, sepsis/meningitis, neonatal convulsions, moderate to severe asphyxia [Sarnat ≥2]) were present. During this period, the general movements of 257 infants were recorded. Sixty-two infants (24%) showed definitely abnormal general movements and were selected to participate in the project. Infants with severe congenital anomalies (*n*=3) and infants whose caregivers had an insufficient understanding of the Dutch language (*n*=1) were excluded from the study. The parents of 12 infants decided not to take part in the project. The parents of the remaining 46 participating infants gave informed consent to participation. The perinatal characteristics of participants and non-participants were similar (Table I). Participants were randomly assigned to two types of intervention: the novel programme COPing with and CAring for infants with special needs – a family-centred programme; COPCA *n*=21) or traditional infant physiotherapy (*n*=25).[8,9] Randomized intervention was applied between 3 months and 6 months corrected age. We have previously reported that the developmental outcome for the two intervention groups was similar.[10,11] The project was approved by the ethics committee of the University Medical Centre Groningen and registered under the trial number ISRCTN85728836.

Assessments at fidgety age

The infants had been assessed when they were at the beginning of the 'fidgety phase', i.e. at a corrected age that varied from 9 to 13 weeks (median value: 10wks and 2d). The assessment consisted of a video recording of at least 5 minutes of spontaneous motor behaviour with the infant in the supine position. The infants had to be in an awake, non-crying behavioural state and wearing minimal clothing. The recordings were performed at the infant's home. For the present study, the video recordings were reanalysed in 2009 to 2010 by AFB and MHA with respect to the following characteristics: the presence of fidgety movements, the degree of complexity and variation, the occurrence of cramped synchronized general movements and stiff or jerky movements, and the spontaneous occurrence of the ATNR pattern (Table SI, supporting material online). The assessors were blinded to any clinical information on the child except for age. To avoid a priori knowledge on general movement quality, the recordings of the VIP infants were mixed with recordings of five infants without definitely abnormal general movements and analysed in random order. First, MHA and AFB assessed the videos

independently. On the few occasions when there was disagreement, details were discussed until a consensus was reached. The focus of the study was not to determine the reliability of the assessment of the specific characteristics but rather to achieve a better understanding on the basis of expert knowledge. It has been well established that general movement quality can be assessed reliably,[13] and Groen et al.[14] reported that details of general movements such as fluent, stiff, and cramped synchronized movements can also be reliably assessed. Both assessors immediately recognized the movement patterns of the infants without definitely abnormal general movements as being characterized by a frequent or continuous presence of fidgety movements, a typical degree of complexity and variation, and absence of the ATNR pattern, cramped synchronized general movements, and stiff or jerky movements.

Follow-up assessments

The developmental status of the infants was assessed in early infancy and at 18 months corrected age. The outcome at the latter age is used in the present study. The assessments were carried out by two PhD students working on the VIP. They knew that the infants had shown definitely abnormal general movements at fidgety age, but were unaware of the movement characteristics evaluated in the present study. Neurological condition was examined according to Hempel.[15] In the current study, neurological condition was classified as the presence or absence of CP. The diagnosis of CP implies the presence of a 'classic' configuration of neurological signs, such as in the case of bilateral spastic CP, the combination of a stereotyped posture and motility in the legs, increased muscle tone and brisk tendon reflexes in the legs, and Babinski signs. The interassessor reliability of the Hempel assessment is satisfactory and its construct validity is good. Children with CP were classified according to the Gross Motor Function Classification System (GMFCS).[16] The GMFCS is an ordered, consistent system for describing gross motor function in children with CP. It classifies children's gross motor abilities in five levels from level I (most able) to level V (most limited). Classification into GMFCS levels before the age of 2 years is good but less precise than in older children.

For evaluation of the quality of spontaneous motor behaviour, the Infant Motor Profile (IMP) was used.[17] The IMP is a video-based instrument consisting of 80 items organized into five domains: variation (i.e. the size of movement repertoire), variability (i.e. the ability to select motor strategies), symmetry, fluency, and performance. It has a good reliability. In the present study only the total IMP scores were used.

The child's gross motor development was assessed by the Alberta Infant Motor Scales (AIMS).[18] The AIMS is designed to identify infants with gross motor delays (until the age of 18mo) and consists of 58 test items administered in four different positions: prone (21 items), supine (nine items), sitting (12 items), and standing (16 items). The reliability and validity of the AIMS is good, but it has a ceiling effect in older infants. However, the ceiling effect occurs considerably less frequently in groups of infants with a substantial risk of developmental problems.

Functional motor outcome was measured with the two mobility scales of the Pediatric Evaluation of Disability Inventory (PEDI): (1) Functional Skills and (2) Caregiver Assistance, evaluating functional capability and performance respectively. The PEDI is a standardized assessment instrument using parental reports in a structured interview. It was developed for children aged from 6 months to 7 years 6 months. The Dutch version of the PEDI was used, which has proven to be reliable and valid.[19]

Cognitive outcome was assessed with the Mental Development Index (MDI) of the Dutch version of the Bayley Scales of Infant Development.[20] The infant's performance on items such as memory learning and problem-solving results in an MDI score. The Bayley Scales of Infant Development is designed to identify children with developmental delay in the age range of 1 month to 3 years 6 months and is the most widely used instrument to assess infant development.

Data analysis

Statistical analysis was performed using SPSS package for Windows, version 16.0 (SPPS Inc., Chicago, IL, USA). To evaluate the relationship between dichotomized general movement characteristics and CP, the Fisher's exact test and chi-squared test were used. The Mann–Whitney *U* test was performed to calculate the relation between categorized general movement characteristics and CP. For the possible association between general movement characteristics and IMP, AIMS, PEDI, and MDI scores, the Mann–Whitney *U* test and Spearman's rank correlation were used (for dichotomized and categorized characteristics respectively). Logistic regression analysis was used to investigate whether there was an interaction between general movement characteristics and intervention. To this end, developmental outcome scores were dichotomized using the 5th centile for IMP and AIMS scores, and the 15th centile for PEDI and MDI scores. Throughout the analyses, differences and correlations with a p value less than 0.05 were considered to be statistically significant (two-tailed testing).

RESULTS

Rate of occurrence of specific general movement characteristics

The rate of occurrence of general movement characteristics is presented in Table II. Remarkably, four children showed frequently or continuously fidgety movements while having definitely abnormal general movements. In all general movements, complexity and variation were absent or present to only a very limited extent, which is in line with the basic characteristic of definitely abnormal general movements. Only five children showed cramped synchronized movements and 11 children exhibited a frequently occurring ATNR pattern. Jerky and stiff movements were observed in 32% and 48% of the infants respectively.

Characteristics of definitely abnormal general movements and CP

Two infants from the traditional infant physiotherapy intervention group did not return to the follow-up assess-

Table II: Rate of occurrence of specific general movement characteristics and cerebral palsy (CP)

Characteristics	Neurological outcome, *n* (%)		
	No CP (*n*=34)	CP (*n*=10)	Total number of children (*n*=44)
Fidgety movements			
Frequent or continuous presence of fidgety activity	3 (75)	1 (25)	4
Some fidgety activity present	18 (86)	3 (14)	21
Sporadic presence of fidgety activity	9 (92)	1 (8)	10
No fidgety activity present	4 (42)	5 (58)[a]	9
Complexity and variation			
Abundantly present	–	–	–
Sufficiently present	–	–	–
Present, but to an insufficient extent	–	–	–
Present to a very limited extent	25 (81)	6 (19)	31
Absent	9 (89)	4 (31)	13
Cramped synchronized			
Frequently or continuously present	0 (0)	1 (100)	1
Occasionally present	3 (75)	1 (25)	4
Absent	31 (79)	8 (21)	39
ATNR pattern			
Occurs frequently or persistently	8 (73)	3 (27)	11
No or variable occurrence	26 (79)	7 (21)	33
Stiff movements			
Majority of movements are stiff	13 (62)	8 (38)[b]	21
Majority of movements are not stiff	21 (91)	2 (9)	23
Jerky movements			
Majority of movements are jerky	13 (93)	1 (7)	14
Majority of movements are not jerky	21 (69)	9 (31)	30
Movement fluency			
Majority of movements are fluent	12 (92)	1 (8)	13
Movements are predominantly jerky	9 (90)	1 (10)	10
Movements are jerky and stiff	4 (100)	0 (0)	4
Movements are predominantly stiff	9 (53)	8 (47)[c]	17

[a]Fidgety activity entirely absent versus sporadic or continuous fidgety activity and CP; Fisher's exact test, p=0.018. [b]Majority of movements are stiff versus majority of movements are not stiff and CP; Fisher's exact test, p=0.031. [c]Predominantly stiff movements versus movements not predominantly stiff and CP; Fisher's exact test, p=0.007. ATNR, asymmetrical tonic neck reflex.

ment at 18 months owing to parental lack of interest in the study. Both infants had shown some fidgety movements and no cramped synchronized movements, ATNR patterning, and stiff movements. One infant showed jerky movements.

Ten infants had developed spastic CP at 18 months corrected age, five in the COPCA group and five in the traditional infant physiotherapy group. Two of the specific general movement characteristics were related to CP (Table II). The presence of predominantly stiff movements in the absence of jerky movements was associated with CP (Fisher's exact test, p=0.007): eight out of the 10 children with CP showed this pattern at 'fidgety age'. Also, the absence of fidgety movements was associated with CP (Fisher's exact test, p=0.018). Four children who showed some or frequent fidgety activity developed CP. Interestingly, the GMFCS levels of these children (levels I or II) indicated that they had relatively mild forms of CP (Table III). Neither the presence of cramped synchronized movements nor the ATNR pattern increased the risk of CP.

Table III: Specific general movement characteristics in infants with cerebral palsy (CP)

Infant	Sex	Fidgety movements	Cramped synchronized movements	ATNR	Stiff movements	Jerky movements	GMFCS level	Uni-/bilateral CP
1	M	+	–	–	Yes	No	I	Bilateral
2	F	++	–	–	No	No	II	Bilateral
3	F	+	–	–	No	Yes	II	Unilateral
4	F	+	–	+	Yes	No	II	Bilateral
5	M	+/–	–	–	Yes	No	II	Unilateral
6	M	–	–	–	Yes	No	II	Bilateral
7	M	–	–	–	Yes	No	III	Bilateral
8	M	–	++	–	Yes	No	III	Bilateral
9	M	–	–	+	Yes	No	III	Bilateral
10	M	–	+	+	Yes	No	V	Bilateral

ATNR, asymmetrical tonic neck reflex; GMFCS, Gross Motor Function Classification System (level I, most able; level V, most limited); M, male; F, female; ++, frequent or continuous presence; +, occasionally present; +/–, sporadic presence; –, absent.

General movement characteristics and additional parameters of developmental outcome

The absence of fidgety movements and the presence of predominantly stiff movements were associated with lower IMP scores (Fig. 1; Mann–Whitney *U* test; p=0.015 and p=0.022 respectively). Infants with stiff movements and those with predominantly stiff movements had lower AIMS scores (Mann–Whitney *U* test; p=0.01 and p=0.004 respectively). The presence of cramped synchronized movements and the ATNR pattern were not related to IMP or AIMS scores. None of the movement characteristics was associated with the PEDI Functional Mobility and Caregiver Assistance scores or the Bayley MDI. The general movement characteristics of the two intervention groups did not differ. Multivariable analyses demonstrated that the associations between general movement characteristics and outcome at 18 months corrected age were not affected by type of intervention.

DISCUSSION

The present study indicated that the power of definitely abnormal general movements at 'fidgety age' to predict CP may be enhanced by paying attention to fidgety movements and movement stiffness, as the absence of fidgety movements and the presence of consistently stiff movements may increase the risk of CP.

The study has two major limitations. First, it was restricted to a small sample of infants with definitely abnormal general movements. This means that our data cannot be extrapolated to the general population of high-risk infants. Second, outcome was evaluated at 18 months of age, which is relatively early for the diagnosis of CP and for determining functional and cognitive outcome. The major strength of the study is the detailed and standardized documentation of movement characteristics of infants with definitely abnormal general movements at the 'fidgety age'.

Previous studies indicated that the absence of fidgety movements is associated with a high risk of CP.[2–5] Our study indicated that also the absence of fidgety movement increases the risk of CP in infants with definitely abnormal general movements. Note that the infants were assessed relatively early in the 'fidgety period', which means that some of the infants may have developed fidgety movements after the assessment. This study also underscores the notion that the presence of fidgety movements does not preclude the development of CP.[21]

Our finding that the assessment of movement stiffness might contribute to the predictive value of definitely abnormal general movements is in line with the findings of others. Bruggink et al.[22] described an association between a cramped motor repertoire at fidgety age and a higher GMFCS level in children with CP. Jerkiness of the motor repertoire was not found to be associated with lower or higher GMFCS levels. Groen et al.[14] indicated that a less favourable developmental outcome at the age of 9 to 12 years was associated with stiff movements at 'fidgety age' but not with the presence of jerky movements. Consistently

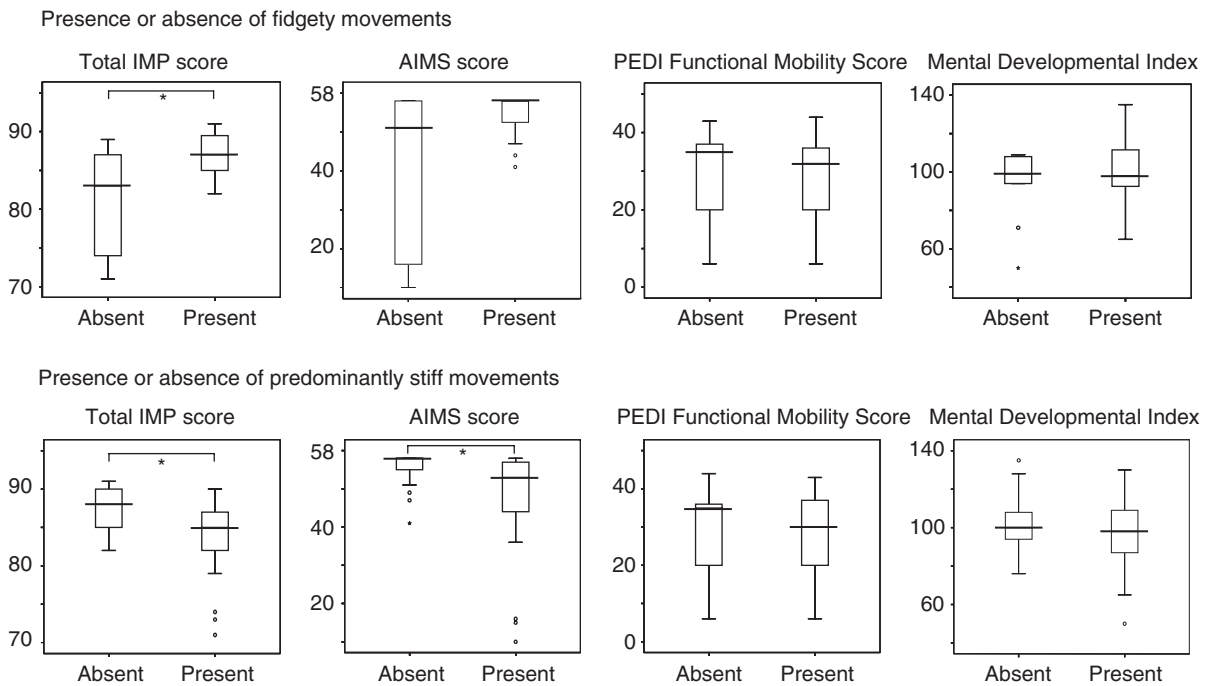

Figure 1: Movement characteristics and developmental outcome at 18 months corrected age. Upper panel: total Infant Motor Profile (IMP) score, Alberta Infant Motor Scales (AIMS) score, Paediatric Evaluation of Disability Inventory (PEDI) Functional Mobility score, and Mental Developmental Index (MDI) (*y*-axes) for infants with (right boxes) or without (left boxes) fidgety movements. Lower panel: total IMP score, AIMS score, PEDI Functional Mobility score, and MDI (*y*-axes) for infants with (right boxes) or without (left boxes) predominantly stiff movements. Data are presented as median values (horizontal bars), interquartile ranges (boxes), and ranges (vertical lines) with outliers (circles). *Mann–Whitney *U* test, p<0.05.

stiff movements can be seen as stereotypy, which may reflect the substantial functional changes in spinal neural networks induced by a loss of supraspinal control, including increased stretch reflex activity.[23]

In the present study, no relation between the presence of cramped synchronized movements or ATNR pattern and developmental outcome was found. In general, cramped synchronized movements are not often observed after 9 weeks corrected age, which might explain the small number of infants with this pattern in our study group. Furthermore, it is conceivable that the absence of these associations may be attributed to the relatively good outcome of the infants studied. Of the 10 children who developed CP, all but one had a GMFCS level between I and III. It is well known that cramped synchronized movements and ATNR patterns are observed in particular in children with more serious forms of CP.[3,24]

The absence of fidgety movements and the presence of stiff movements were associated not only with CP but also with lower IMP scores, and only stiff movements were associated with lower AIMS scores. However, these two movement characteristics were not related to functional mobility in terms of PEDI scores nor to cognitive outcome at 18 months corrected age. This suggests that the additional movement characteristics at fidgety age may improve the prediction of later body function, i.e. motor impairment, but may not facilitate prediction of the child's function at the levels of activity and participation in the International Classification of Functioning, Disability and Health–Children and Youth version.[25] Future studies should address the question of whether movement characteristics at fidgety age are related to cognition, activity, and participation at school age and beyond, as these functions change considerably with increasing age.

In conclusion, the present study indicates that the absence of fidgety movements and the presence of predominantly stiff movements may improve the predictive power of definitely abnormal general movements for later motor impairment, in particular CP. This notion deserves further investigation in larger populations followed at least until school age.

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ONLINE MATERIAL

Additional material and supporting information may be found in the online version of this article.

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