

Assessment of gross motor development in the WHO Multicentre Growth Reference Study

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Abstract

The objective of the Motor Development Study was to describe the acquisition of selected gross motor milestones among affluent children growing up in different cultural settings. This study was conducted in Ghana, India, Norway, Oman, and the United States as part of the longitudinal component of the World Health Organization (WHO) Multicentre Growth Reference Study (MGRS). Infants were followed from the age of four months until they could walk independently. Six milestones that are fundamental to acquiring self-sufficient erect locomotion and are simple to evaluate were assessed: sitting without support, hands-and-knees crawling, standing with assistance, walking with assistance, standing alone, and walking alone. The information was collected by both the children's caregivers and trained MGRS fieldworkers. The caregivers assessed and recorded the dates when the milestones were achieved for the first time according to established criteria. Using standardized procedures, the fieldworkers independently assessed the motor performance of the children and checked parental recording at home visits. To ensure standardized data collection, the

sites conducted regular standardization sessions. Data collection and data quality control took place simultaneously. Data verification and cleaning were performed until all queries had been satisfactorily resolved.

Key words: Child, child development, infant, longitudinal study, motor development, motor skills

Introduction

Motor behavior is an essential aspect of child development. Given the unique opportunity provided by the World Health Organization (WHO) Multicentre Growth Reference Study (MGRS), a component to assess gross motor development was included in the protocol. Motor development is usually assessed in terms of age of achievement of motor milestones [1]. Besides the determination of age at attainment, longitudinal assessment of different types of motor skills has the advantage of providing a profile of their sequence and tempo [2, 3]. However, few studies using a longitudinal design have been done on the age of achievement of certain motor milestones [4–21], and only two of them are of a multicountry nature [10, 21].

To our knowledge, this is the first longitudinal study that has used a standardized protocol to describe gross motor development among groups of children with no health, environmental, or economic constraints on growth, living in different countries. The study sample described by the WHO Task Force for Epidemiological Research on Reproductive Health [21] was stratified into three different socioeconomic-level groups, and the study of Hindley et al. [10] was limited to the assessment of one motor milestone. The MGRS aimed to fill this gap in information by collecting data on six gross motor milestones in five of the countries participating in its longitudinal growth and development study: Ghana, India, Norway, Oman, and the United States. Under the umbrella of the MGRS, the Motor Develop-

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ment Study provides a unique opportunity to assess group and individual variability in the acquisition of key motor skills, as well as providing an opportunity to analyze the relationship between physical growth and gross motor development among groups of affluent children growing up in different cultural settings.

This paper outlines the Motor Development Study protocol for collecting information on six motor milestones, the methods and procedures of data collection, and the training and standardization of fieldworkers.

Methods

Study subjects and study design

The motor development assessments were done from the age of four months on all subjects enrolled in the longitudinal component of the MGRS. Details of the enrollment of subjects, the inclusion criteria, and the MGRS study design are explained elsewhere in this supplement [22]. The study took place in five of the six countries participating in the MGRS: Ghana, India, Norway, Oman, and the United States. The implementation of the study protocols in each of these countries is described in separate papers in this supplement [23–27]. The Brazilian site was unable to participate in the Motor Development Study because the site had initiated data collection by the time the decision to assess motor development was taken.

Gross motor milestones: description, criteria, and testing procedure

Six distinct gross motor milestones were selected for study: sitting without support, hands-and-knees crawling, standing with assistance, walking with assistance, standing alone, and walking alone. These milestones were selected because they are considered to be universal, fundamental to the acquisition of self-sufficient erect locomotion, and simple to test and evaluate.

Before the achievement of any of the six motor skills, the child goes through many preceding intermediate stages of development [28, 29]. Evaluation of a milestone performance consists in observing not only what a child does, but also how and with what level of development he or she does it [29]. There is also a need to include in the criteria for testing whether a child can perform a milestone independently or performs it after having been placed into position [30]. Thus, in order to minimize interpersonal interpretation differences, each test item needed to be clearly defined with respect to the method of administration and the interpretation of the child's performance [1].

The descriptions of the six gross motor skills used in this study originated from various existing developmental scales [2, 29, 31–35]. The sequential presentation of the motor milestones followed the pattern generally found in the literature [36–40]. However, occasionally the suggested sequence between two or more milestones might actually be reversed, and observed milestones might be inhibited later [28]. Therefore, no fixed developmental sequence of achievement was assumed.

All milestones were assessed using standardized

TABLE 1. MGRS performance criteria for six gross motor milestones

Gross motor milestone	MGRS performance criteria
Sitting without support	Child sits up straight with the head erect for at least 10 seconds. Child does not use arms or hands to balance body or support position
Hands-and-knees crawling	Child alternately moves forward or backward on hands and knees. The stomach does not touch the supporting surface. There are continuous and consecutive movements, at least three in a row
Standing with assistance	Child stands in upright position on both feet, holding onto a stable object (e.g., furniture) with both hands without leaning on it. The body does not touch the stable object, and the legs support most of the body weight. Child thus stands with assistance for at least 10 seconds
Walking with assistance	Child is in upright position with the back straight. Child makes sideways or forward steps by holding onto a stable object (e.g., furniture) with one or both hands. One leg moves forward while the other supports part of the body weight. Child takes at least five steps in this manner
Standing alone	Child stands in upright position on both feet (not on the toes) with the back straight. The legs support 100% of the child's weight. There is no contact with a person or object. Child stands alone for at least 10 seconds
Walking alone	Child takes at least five steps independently in upright position with the back straight. One leg moves forward while the other supports most of the body weight. There is no contact with a person or object



FIG. 1. Sitting without support

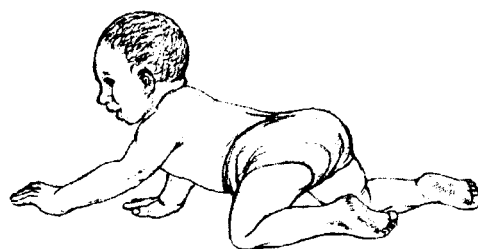


FIG. 2. Hands-and-knees crawling

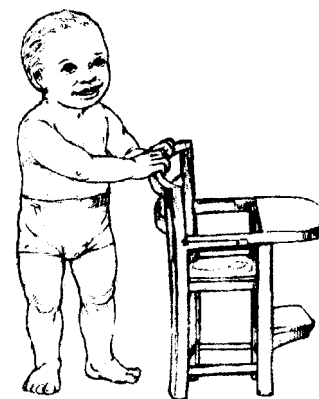


FIG. 3. Standing with assistance

testing procedures. Table 1 describes the MGRS performance criteria for the six milestones. A milestone was considered achieved only if all the given criteria were met.

Sitting without support (fig. 1)

Description. The child is able to balance the weight of the trunk and head without any external support or the use of arms and hands. The child sits up straight with the head erect (that is, not leaning forward). One of the lower limbs is usually flexed.

Criteria. (a) The child's head is erect; (b) the child does not use the arms or hands to balance body or support position; (c) the child sits up straight for at least 10 seconds.

Testing procedure. Facing the child and smiling, the fieldworker places the child in a sitting position. The fieldworker then gives the child a toy to handle with both hands so that he or she is not able to use the arms to support himself or herself.

Hands-and-knees crawling (fig. 2)

Description. This is a phase of a more organized prone movement that refers to the palm-knee position, with alternating movements of the upper and lower limbs: the right arm and left leg move forward or backward synchronously and vice versa in similarly ordered consecutive movements.

Criteria. (a) Alternating movement forward or backward on hands and knees; (b) the child's stomach does not touch the supporting surface; (c) continuous and consecutive movements, at least three in a row.

Testing procedure. The fieldworker places the child in the prone position with the abdomen above the supporting surface. The fieldworker places himself or herself in front of the child, about 120 to 150 cm away. If the child does not crawl spontaneously, the fieldworker shows the child a toy or object that attracts the child's visual attention. The fieldworker (sometimes with the help of the caregiver) then tries to coax the child to crawl toward the toy and grab it.

Standing with assistance (fig. 3)

Description. This is the first direct step toward erect bipedal locomotion, in which the child is for the first time challenged to maintain some balance of the whole body weight so that he or she can move forward. The salient characteristic is whether the child can actually support his or her weight if he or she is holding onto a stable object (e.g., a piece of furniture) with both hands without leaning over or resting the body on the stable object.

Criteria. (a) The child is in an upright position on both feet; (b) the child holds onto a stable object with both hands without leaning on it; (c) the child's body does not touch the stable object; (d) the child's legs support most of the child's body weight; (e) the child thus stands with assistance for at least 10 seconds.

Testing procedure. The fieldworker places the child in a standing position so that the legs support the body weight. The child is placed at a distance from which both hands, but not the body, can reach and hold onto a stable object. Thus, most of the body weight is supported by the child's own feet. The fieldworker should check that the child is not leaning over or resting his or her body on the stable object. The height of the stable object should be at about the same level as the child's stomach.

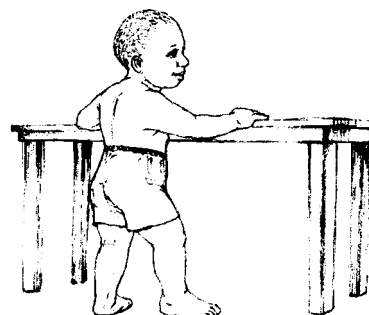


FIG. 4. Walking with assistance

Walking with assistance (fig. 4)

Description. This involves a deliberate attempt to make stepping movements and to make postural adjustments toward this end while holding onto a stable object (e.g., furniture) for support.

Criteria. (a) The child is in an upright position with the back straight; (b) the child makes sideways or forward steps by holding onto a stable object with one or both hands; (c) one leg moves forward while the other supports part of the body weight; (d) the child takes at least five steps in this manner.

Testing procedure. The fieldworker places the child in a standing position so that the legs support most of the body weight. The child is placed at a distance from which he or she can reach and hold onto a stable object with one or both hands. If the child does not move spontaneously, the fieldworker shows the child a toy or object that attracts the child's visual attention. The fieldworker (sometimes with the help of the caregiver) then tries to coax the child to walk toward the toy and grab it. The height of the stable object should be at about the same level as the child's stomach.

Standing alone (fig. 5)

Description. The child shows the capacity for both equilibrium and sustaining body weight on the feet. In this position the child's legs show no flexion, and the child is standing on the feet (not on the toes) without leaning over or holding onto an object. The child maintains continuous balance independently.

Criteria. (a) The child is in an upright position on both feet (not on the toes) with the back straight; (b) the child's legs support 100% of the child's weight; (c) there is no contact with a person or an object; (d) the child stands alone for at least 10 seconds.

Testing procedure. The fieldworker places the child with both feet flat on the floor and supports the child to an erect position. Then the fieldworker withdraws the support gradually and temporarily to determine

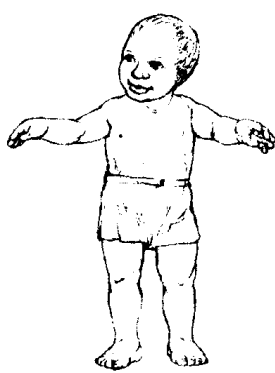


FIG. 5. Standing alone

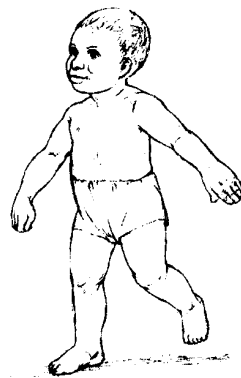


FIG. 6. Walking alone

whether the child can modify posture, adjust to the new position, and stand alone for at least 10 seconds.

Walking alone (fig. 6)

Description. The child shows the capacity to balance the body and to control his or her forward stepping movements. There is no need for assistance, because both the postural adjustment and the stepping movements are engaged in independent walking. An important indicator of this phase of erect locomotion is that movement of the entire body does not accompany the child's stepping movements. This phase does not refer to the child's first independent steps when the child is able to take three or four uncertain steps toward the adult's outstretched hands.

Criteria. (a) The child is in an upright position with the back straight; (b) one leg moves forward while the other supports most of the body weight; (c) there is no contact with a person or an object; (d) the child takes at least five steps independently.

Testing procedure. The fieldworker places the child in an erect position out of the reach of any supporting object. Then the fieldworker takes a position about 120 to 150 cm in front of the child and calls the child to move toward the fieldworker. Sometimes, the caregiver needs to encourage the child.

The child's emotional state

Because emotional arousal can either enhance or undermine motor behavior, the fieldworker rated the overall emotional state of the child during the testing of all the six gross motor milestones according to two scales [41]. First, the scale of consciousness was rated either as drowsy or as awake and alert. Second, the child's irritability was rated as being calm, fussy, or upset (crying).

Ideally, the child should be awake, alert, and calm during the assessments of motor skills. Drowsiness, fussiness, and crying were not reasons for not testing if the child was still able to display the milestone under testing. However, if they interfered with assessment, the child was retested when he or she was calm. If a child was asleep, he or she was not woken up to be tested.

In the context of the MGRS, the fieldworkers preferably tested the child on the motor skills after the completion of the anthropometric measurements. However, if the child was known to become upset by the anthropometric measurements, testing on motor milestones occurred prior to these measurements. If the caregiver and/or the child were obviously distraught or if the child was sick during a follow-up visit, testing did not occur.

Training and standardization of fieldworkers

Training

The MGRS fieldworkers selected to carry out the motor development assessments were trained at their own study site by an external expert prior to the initiation of data collection. The training involved lectures, discussions, observations, and assessments of a group of about 30 children (aged 5–13 months). It consisted of two days of initial training, one day of evaluation of the trainees, and two days of guided home visits. During the two-day initial training, the assessments carried out by the trainees were videotaped and reviewed afterwards by the trainer and trainees. The evaluation session (which was recorded as well) assessed the trainees' ability to score the achievement of the six motor milestones. This session involved both trainer and trainees. The trainer tested and scored approximately 10 to 15 children (aged 5–13 months) and did not give any indication of the children's scores to the caregivers or trainees. The trainees observed the child being tested and independently scored the child's performance on each tested skill. After the evaluation, the trainees' scores were compared with the trainer's scores, and in case of disagreements, these were discussed by looking at the videotaped session.

Standardization

The sites conducted regular half-day standardization sessions to determine the interobserver reliability rates of fieldworkers. During each session, one member of the fieldworkers' team tested and scored a group of about 10 children (aged 6–12 months) for the six motor milestones. The assessment and performance of the children were videotaped for subsequent scoring by the other fieldworkers at the same site. At each session, the fieldworker doing the actual testing was rotated so that a different person was the tester. The child's caregiver was present but was requested not to interfere with the assessments. However, when needed, the tester asked for the caregiver's assistance. The tester did not give any indication of the child's scores and wrote them on a standardization record form. Milestone performance could be rated as inability, refusal, ability, or unable to test, according to the established criteria (see below). The other fieldworkers watched the videotaped session and independently scored the performance of the same children on each of the six milestones.

After the conduct of each session, the videotape of the session and the fieldworkers' scores were sent to the Coordinating Centre of the MGRS at WHO in Geneva. The Motor Development Study coordinator on the Coordinating Centre team viewed the tape and scored the performance of the children. The scores given by the coordinator were considered to be the standard (true) scores. Interobserver reliability rates (percent-

ages of agreement) were generated by calculating a correlation between the standard score and the scores obtained by the tester and the observers in a site.

The results of the sessions and comments on the observed disagreement between the standard score and a fieldworker's score, as well as on the tester's performance of the assessments, were sent as feedback to the site. A cutoff point of 90% agreement was set to determine whether further training was required.

Standardization of conditions for testing

It is well documented that child rearing practices [42] and encouragement by training and practice [28, 43] account for part of the variability in the achievement of motor milestones. Data collection in the study took place at the children's homes so that the standardization of the environment was limited. One source of variability, however, that could be controlled for was the social and physical context in which the child was tested and the nature of the objects used for testing. If physically possible and culturally appropriate, the number of persons present during testing was limited to three (fieldworker, caregiver, and child). If limitation of the number of people in the room was not possible, it was imperative that other observers did not move or make verbal comments during testing unless requested. Ideally, the surface of the floor where the assessments took place was clean and free of objects that might interfere with locomotion. Prior to testing, the fieldworker asked the caregiver to select a maximum of three toys or objects that the child liked to play with. It was primarily the fieldworker who carried out motor development assessment during the home visits. However, in some cases it was necessary for the fieldworker to ask for the caregiver's help.

Data collection

The data were recorded by the child's caregivers between follow-up visits and by the trained follow-up team members during these scheduled visits to the children's homes.

Caregiver

At the four-month follow-up visit, the caregiver was informed about the Motor Development Study and asked to start observing and assessing the child's motor developmental level until the child had achieved all six milestones. The caregiver was told to place the child in the appropriate position according to the defined testing procedures as soon as the caregiver observed that the child was making the first movements toward the achievement of a particular milestone. No fixed order of milestone achievement was assumed.

The record form for the caregiver had one page and presented the six drawings of the milestones (figs.

1–6), along with the performance criteria. A date box for each milestone was given, in which the caregiver recorded the date the child met the criteria for this item and thus achieved it for the first time. As soon as the caregiver had recorded the dates of first appearance of all six milestones, the caregiver stopped the motor development assessments.

Fieldworker

The follow-up team member trained in motor development assessments tested and scored all of the six gross motor milestones at each home visit. When both fieldworkers doing the home visits had been trained in motor development assessment, only one of them carried out the assessment and scored the child without the involvement of the other fieldworker. It was not necessary that the same fieldworker carry out all the motor development assessments for a given child. Motor development assessments were carried out monthly during the first year of life, starting from the five-month visit, and then every two months in the second year of life until the child acquired the skill of independent walking. If at the four-month visit, the time point when the fieldworker informed the caregiver about the study, the fieldworker observed that a child had achieved a certain milestone or a caregiver reported its achievement, then the fieldworker started the assessment at that visit. The reasons for examining all the milestones at each home visit were standardization of data collection across study sites, the fact that motor milestones might not occur in a sequential way in all subjects, and the fact that some milestones might be observed and then inhibited later (e.g., after an illness or trauma).

The performance of each milestone was evaluated independently by using four coding possibilities: inability—the child tried but failed to perform the test item because it surpassed his or her developmental level; refusal—the child was calm and alert but just refused to cooperate; ability—the child performed the test item according to the specified criteria; and unable to test—the child could not be tested on this milestone because his or her emotional state (drowsiness, fussiness, or crying) was interfering with testing, the child was sick, or the child's caregiver was distraught. In practice, it was somewhat difficult to differentiate between “refusal” and “unable to test.”

The fieldworker took about 10 minutes to test all milestones. Since it was not always possible to get the child's cooperation immediately, the fieldworker was allowed three trials for the assessment of each milestone. The fieldworkers were given no ages at which the infants were expected to achieve each milestone, as this might have influenced their judgment.

For milestones that had not been achieved by the 12-month visit, the fieldworkers called the caregivers in the months with no scheduled follow-up visit during the

second year of follow-up (i.e., months 13, 15, and 17). The fieldworker asked whether the child had achieved a specific milestone and reminded the caregiver to fill out the parent's record form. If the child had achieved a specific milestone, the fieldworker verified this by going through the criteria with the caregiver on the phone. Afterwards, at the planned home visit the following month, the fieldworker checked the acquisition of the reported milestone. Figure 7 shows the data collection form used by the fieldworkers for the motor development assessment.

Parental recording

At each visit, the fieldworker asked the caregiver about the milestones achieved since the previous follow-up visit and obtained the date that the caregiver had written down on the record form. If it was found on examination that the milestone(s) reported by the caregiver had not actually been attained by the child, the fieldworker carefully discussed this with the caregiver and explained the criteria again to make sure that the caregiver understood the criteria for the specific milestone. If the caregiver agreed that the child did not fulfill all the criteria, the fieldworker drew a new date line below the recorded date on the parent's record form for the milestone involved and asked the caregiver to record the date when this milestone was achieved according to the established criteria. If, on the other hand, the caregiver was sure that the child had met the criteria for the milestone, the fieldworker transferred to the form (fig. 7) the first written date as the caregiver's recorded date. The fieldworker also verified whether the caregiver had actually tested and recorded the date or simply recalled the date of first achievement. If a child happened to perform the motor skill for the first time at a certain home visit, this date was entered as the caregiver's date. The fieldworker never told the caregiver when a child should be achieving a particular milestone or gave any indication about which milestones the caregiver should be looking for as the child got older.

Data quality control

Data quality assurance started with the fieldworkers carefully filling out the record forms and checking for completeness and accuracy. Additional checks were made by data quality control staff and supervisors at the sites. Extensive quality checking was carried out on the data accumulated at the Coordinating Centre. A printout of the complete set of Motor Development Study records for each child was checked periodically for inconsistencies, such as missing or incorrectly entered caregiver's dates, reported caregiver's date without confirmation of a milestone's achievement by a fieldworker, discontinuation of the Motor Development Study without observed achievement of all


 WORLD HEALTH ORGANIZATION		Multicentre Growth Reference Study Project NUT01 – Motor development assessment		MDS	
Identification		Test items	Examiner report (a) Observed 1 = No (inability) 2 = No (refusal) 3 = Yes 9 = Unable to test	Caretaker report (b) Precise date of first achievement (Taken from the parent's record form). Only enter date(s) for milestone(s) achieved for the first time between the previous follow-up and present visit.	(c) Type of record 1 = Tested and recorded 2 = Recalled
(a) Form code:	MDS	1. Sitting without support	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(b) Study number:	NUT01	2. Hands-and-knees crawling	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(c) Site number:	<input type="checkbox"/>	3. Standing with assistance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(d) Subject code:	<input type="checkbox"/> - <input type="checkbox"/>	4. Walking with assistance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(e) Follow-up visit number:	<input type="checkbox"/>	5. Standing alone	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(f) Continued testing required? 1 = No 2 = Yes	<input type="checkbox"/>	6. Walking alone	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(g) Date of visit:	<input type="checkbox"/> / <input type="checkbox"/> / <input type="checkbox"/> Day Month Year	7. Child's emotional state Rate the child's emotional state during the testing of all the milestones. Enter a code for each of the two scales.		(a) First scale 1 = Drowsy 2 = Awake and alert	(b) Second scale 1 = Calm 2 = Fussy 3 = Crying
(h) Examiner's code:	<input type="checkbox"/> <input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>
Remarks					

FIG. 7. Fieldworker's data collection form for motor development assessment

six milestones, or order of milestone achievement (e.g., walking alone before walking with assistance). The reported inhibition of a milestone was queried as well as differences between a Motor Development Study home visit date and a follow-up visit date. The inconsistencies were sent to the sites for investigation, verification, and correction at the source. This process of data verification and cleaning between the sites and the Coordinating Centre was continued until all data queries had been satisfactorily resolved. Detailed descriptions of the MGRS data management procedures are given elsewhere in this supplement [44].

Conclusions

The Motor Development Study aimed to describe the acquisition of six universal gross motor milestones in the first two years of life among affluent children growing up in different cultural settings, and thereby fill an existing gap in knowledge. The uniqueness of this study includes the opportunity to link growth and motor development in one international reference. The same protocol was used in the five countries that participated in the study, and the motor development assessments were performed by standardized fieldworkers. This is expected to minimize the influence of respondent biases on the outcome. At the

same time, having caregiver records of the exact dates of milestone achievement facilitates internal cross-validation with fieldworkers' records and comparison of the MGRS data with previous studies that relied on parental reporting alone. Achievement of the six milestones was assessed repeatedly between 4 and 24 months of age, which will make it possible to describe their sequence and tempo in addition to the ages when milestones were acquired. The availability in the MGRS of information on breastfeeding and complementary feeding will also permit studies of associations between child feeding and motor development.

Although the study was conducted in a standardized manner, it also had limitations. We did not collect information on stimulation and child rearing practices that might influence milestone acquisition [28, 42, 43]. Thus, although it will be possible to examine associations between motor development and child feeding, morbidity, and overall physical growth, assessment of the possible influence of psychosocial stimulation on the reported outcomes will be limited to the examination of their ecological associations with the socioeconomic and demographic profiles found in the MGRS. Despite this limitation, this study provides an important addition to the literature on gross motor development in different cultural settings and should serve as a baseline for more focused studies of both motor and cognitive development.

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