Method for the kinematic analysis of kicking movement in infants

Método para análise cinemática dos chutes de lactentes

Método para el análisis cinemático de los pataleos de lactantes

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ABSTRACT | The aims of this study were to describe the method used for the kinematic analysis of kicking movements in infants and test its feasibility of use, using the Dvideow system. To adjust the method, four infants were longitudinally videotaped at ages from one to six months in the supine position. The experiment lasted two minutes, divided into two conditions: training and observation. The Dvideow system 6.3 for image analysis was used. It was verified that the use of four video cameras was more appropriate for the visibility of two markers simultaneously, allowing 3D reconstruction of motion. Moreover, 6 plumb lines were used to calibrate the system and ensure an accuracy of 2 mm. It was concluded that the use of the Dvideow system to perform kinematic analysis of the kicking movement in infants proved to be appropriate and feasible, since this system is accessible, of low cost and easy to be used for researchers in general.

Keywords | infant; lower extremity; child development; biomechanics.

RESUMO | Os objetivos deste estudo foram descrever o método utilizado para a análise cinemática dos movimentos de chutes em lactentes e testar sua viabilidade de uso, empregando o sistema Dvideow. Para adequação do método, quatro lactentes foram filmados, longitudinalmente, nas idades de um a seis meses na posição supina. O experimento teve a duração de dois minutos, subdivididos em duas condições: treinamento e observação. O sistema Dvideow 6.3 foi utilizado para análise das imagens. Foi verificado que o uso de quatro câmeras de vídeo é mais apropriado para garantir a visibilidade de dois marcadores, simultaneamente, permitindo a reconstrução tridimensional do movimento. Além disso, utilizamos 6 fios de prumo para calibrar o sistema e garantir uma precisão de 2 mm. Portanto, concluímos que a utilização do sistema Dvideow para realizar a análise cinemática dos chutes de lactentes mostrou-se adequada e viável, uma vez que esse sistema é acessível, de baixo custo e de fácil utilização para os pesquisadores em geral.

Descritores | lactente; extremidade inferior; desenvolvimento infantil; biomecânica.

RESUMEN | Los objetivos de este estudio fueron describir el método utilizado para el análisis cinemático de los movimientos de pataleo en lactantes y probar su factibilidad de uso, empleando el sistema Dvideow. Para la adecuación del método, cuatro lactantes fueron filmados, longitudinalmente, en las edades de uno a seis meses en la posición supina. El experimento tiene una duración de dos minutos, subdivididos en dos condiciones: entrenamiento y observación. El sistema Dvideow 6.3 fue utilizado para el análisis de las imágenes. Fue verificado que el uso de cuatro cámaras de video es más apropiado para garantizar la visibilidad de dos marcadores simultáneos, permitiendo la reconstrucción tridimensional del movimiento. Además, utilizamos seis alambres de plomo para calibrar el sistema y garantizar una precisión de 2 mm. Por lo tanto, concluimos que la utilización del sistema Dvideow para realizar el análisis cinemático de los pataleos de lactantes se mostró adecuada y viable, ya que éste sistema es accesible, de bajo costo y de fácil utilización para los investigadores en general.

Palabras clave | lactantes; miembros inferiores; desarrollo; cinemática.

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INTRODUCTION

In recent decades, to study the movement of infants with typical or atypical development, researchers have used the kinematic analysis. Analyze cinematically movement is to obtain spatial coordinates for the location of anatomical landmarks defined in the body, while conducting a motor action. Using these coordinates, it is possible to obtain quantitative variables that describe the movement of the body segments. Especially in the motor development area, there are big advances in understanding of the acquisition and improvement of various motor skills in infants, being the kinematic analysis the method employed in the manual range[1-4], the spontaneous kicks[5,6] and the movement[7-9].

The spontaneous kicks are examples of the earliest observed behaviors in infants[10] and is believed to play an important role in the development of bipedal locomotion[11]. By kinematic analysis, it has been shown that the spontaneous kicks have spatial and temporal structure similar to the mature human locomotion[12]. Some authors found the influence of mobile kicks in spontaneous, showing that infants at the age of four months old learned to play a foot panel to activate the crib mobile[10]. Other authors investigated the effect of unilateral weight in infants in the ages of 6, 12, 18 and 26 weeks, which resulted in changes in the kick behavior, in the ages of 6 and 12 weeks, in the kicks frequency range of motion and in the peak speed of both legs[13]; and investigated the contribution of dorsal root cortic tract in the regulation and coordination betwen limbs and spatio-temporal organization of the infants kicks with and without the addition of periventricular leucomalacia unilateral weight, they find some differences, which could not be assigned to the dorsal root cortic influences[14]. For this objective, analysis systems as OPTOTRAK 3020 motion analysis system sensors (Northern Digital Inc., Waterloo, Ont., Canada) and VIDIPLUS (Vrije Universiteit, Amsterdam, the Netherlands) have been used in the study of infants kicks. The importance of studies that explore this specific behavior, enlarging the knowledge development and motor behavior. However, the specific methodology to carry out those studies may not be accessible to the entire scientific community due to the high cost of systems available.

In Brazil, we use the Dvideow system for the study of infant movement, which has been applied in the studies of the manual range[15] and vision-encephalic coordination[16]. Also, because its facility to use, this system can be used to study many behaviors.

The Dvideow system (Digital Video for Windows 32-bit for Biomechanics) was developed by the teams of Biomechanical Instrumentation laboratory (College of physical education) and the Institute of computing of the State University of Campinas (UNICAMP), and consists mainly in non-dedicated equipment and a computer program[17,18].

Some advantages in using this system are: it cost less comparing to others. Also, as with other equipment, it is not necessary to use cables, and markers can fit to the studies with infants. According to themarcadores authors, it is possible that specific characteristics of markers placed in anatomical points of the body can be used as a pattern to be identified in the sequence of images, allowing the automatic tracking of these points during the whole exercise. The three-dimensional reconstruction of the movement can be obtained quickly and accurately, optimizing the analysis time.

Although the system has been used in the three-dimensional reconstruction of adults and babies, it had not been used yet for reconstruction of spontaneous kicks. Therefore, a methodological study to check aspects such as the positioning and the number of cameras, calibration system definition, the placing of markers, reconstruction of the movements and definition of variables is necessary. Therefore, the objectives of this work were to describe the method used for the analysis of kinematics kicks in infants and test their feasibility of use, using the Dvideow system.

METHODOLOGY

The method will be described according to the steps required for three-dimensional reconstruction of the movement: 1) Assembly calibration system; 2) placement and number of cameras; 3) test procedures.

Calibration system

To perform the three-dimensional reconstruction of the movement, it is necessary that the movement

happens within a volume calibrated with known measures. For do this two calibration systems were tested. The system 1 was composed by 4 steel wires, 2.30 m long, forming a cube in the center of the evaluation room that with dimensions of 0,48x0,32x0.35 m^3. At the lower end of each wire a 50 g cone was attached. In the wires were fixed 10 markers (1 cm diameter), at a distance of 10 cm from each other, as shown in Figure 1A. For the system 2, was built a volume consisting of six steel wires, 2.30 m in length, arranged to form a rectangle in the center of the room with a volume of 0,64x0,84x0.35 m^3. At the lower end of each wire was attached a 400 g cone. over the wires were fixed 25 markers (0.5 cm in diameter), at a distance of 5 cm from each other, as shown in Figure 1B. The XYZ coordinates of both systems were measured using a theodolite mechanic and a measuring tape from 3 m with- graduation in millimetres. The X-and Y-coordinates are the coordinate plane, and the Z-coordinate was taken as the height difference between the markers and the original point of the system[19].

An accuracy test was performed to check for the margin of error in both calibration systems. So, a wire with two markers fixed on the upper extremities was used, with a 30 cm distance, which was filmed while the examiner moved it in different directions inside the volume, in both calibration systems, for a minute. Afterwards, these images were rebuilt; the distance between the wire markers and the accuracy were calculated by the following formula: A2=b2+p2, in which b is the bias of the measurements, given by the deviation between the mean value of the set of measurements and the expected value, and p is the measurement of the dispersion of a set of data in relation to the mean value, given by the standard deviation of experimental measurements[19].

Placement and number of cameras

The Dvideow system allows the use of up to six video cameras and point was the infants legs, it was necessary to divide the analysis into two, one for each lower limb. For data registration, two placements conformations and two cameras were possible. For

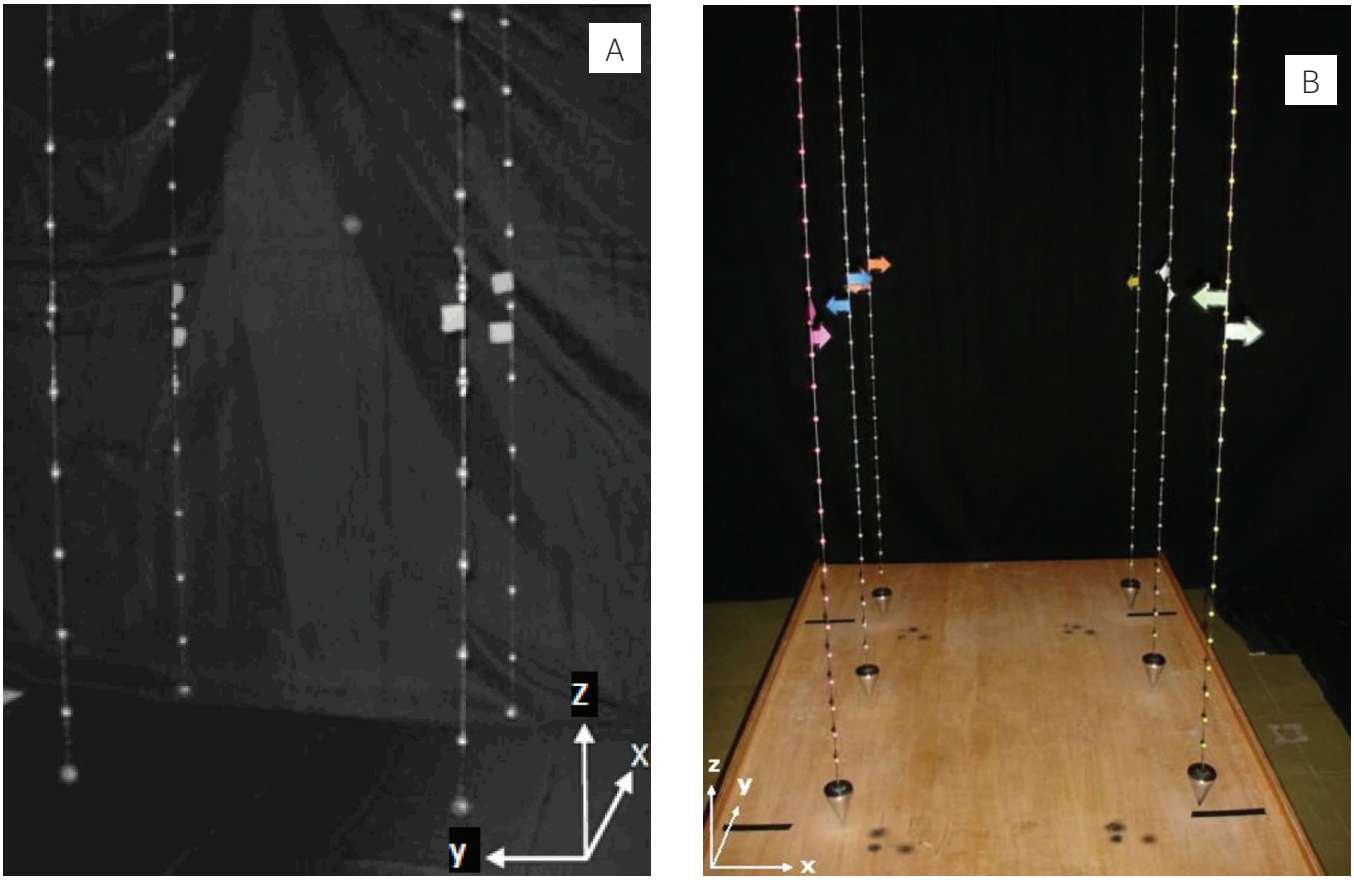

Figure 1. Calibration. (A) System 1, with four-wire; (B) System 2, with six wires

conformation 1, we used three JVC digital video cameras (GY model DV-300), positioned on tripods. After that a camera was positioned in examination table at a height of 2 m above the ground, while the other two were positioned anterolaterally on the platform, forming an angle of 60° to each other, with 1.2 m height from the ground. For motion analysis performed with the right lower limb, we analyzed the images from the cameras from the right and posterossuperior, and for analysis of left lower limb kicks, were analyzed the images from the cameras left and posterossuperior.

For the conformation 2, we used four digital video cameras and three JVC (model GY DV-300) and a Sony (DCR-TRV30), coupled to tripods. Two cameras were positioned on each side of the stage, forming an angle of 120° to each other, being the right cameras used to record images of the right lower limb, and the left, to the left lower limb. The height of the cameras from the ground was approximately 1.4 m. The two conformations have been tested as it is in Figure 2.

Two lights (with 500 W lamp) with diffusers were directed to the wall so that the markers reflect properly and not disturbed the infants vision.

After the definition of calibration, system position and number of cameras, test procedures were carried out with the babies for analyzing the feasibility of such methodology for the reconstruction of spontaneous kicks.

Before each data collection, system calibration was performed, setting the camera to manual control to adjust the white balance, focus and aperture shutter speed according to the lighting used and the desired precision. The image framing was carried out so that the wires were filmed for one second period. Then, the wires were removed and the infant examination table was positineted. The cameras still on mode ON until the end of the evaluation. The objective was to not change the camera settings, ensuring the reliability of the taken measures.

Test procedures

To analyze the method of the kick study, it was necessary to test a sample of four healthy infants, two male and two female, born at term (38.75±0.5 weeks of gestational age), with Apgar score equal to or greater than 8 in the first minute (8.25±0.5) and 9 in the 5th minute (9.25±0.5) and with appropriate weight to the gestational age (3,331±416.62 g). The subjects were selected by consulting medical records in a basic health Unit. During the evaluation, the baby should be in a state of active or inactive alert (grades 3 and 4)[20].

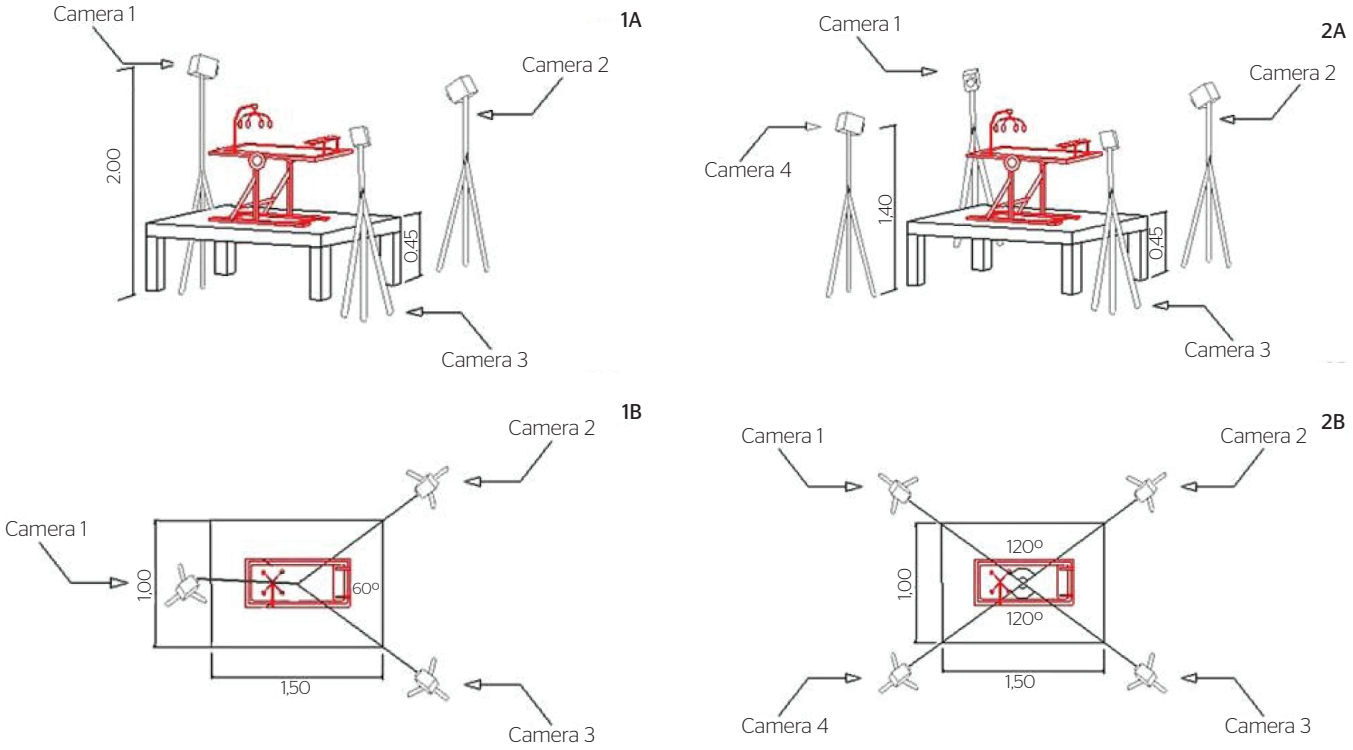

Figure 2. Experimental arrangement: 1A and 2A: schematic perspective of systems 1 and 2, respectively; 1B and 2B: schematic plan of systems 1 and 2, respectively

The evaluation was performed in the interval between feedings so that hunger or satiety does not interfere in infant behavior.

This study was approved by the Committee of ethics in research with Human Beings at the Federal University of São Carlos (UFSCar), and parents of infants have signed an informed consent. The study was conducted in the Laboratory of Research and Analysis of the Movement (LaPAM) of UFSCar.

The four infants were filmed once a month, from the first to the sixth month age. These evaluations were carried out for the dates of birthday, considering a range of seven days before or after the date.

In the laboratory, the infant was undressed by her mother and the examiner collected anthropometric data of weight, height and lengths of the infants legs. Then, bilaterally markers have been fixed on the trunk (intersection of midline and last rib) and in the lower limbs, in the following anatomical references: anterosuperior iliac spine, trochanter of femur, lateral epicondyle of the femur, lateral malleolus and fifth metatarsal base[21].

The infants were positioned in supine in children's examination table[22]. At the lower end of the table, a panel was set (0,30x0.10 m), that drive a mobile in a higher position(Figure 3) with visual and auditory stimulus, such as reinforcement to encourage movements of the kick panel. The lower limb length measures were used for the definition of the positioning of the height of the panel attached to the table: [(leg length) x sen (30°)[10])]. To keep the infant safe and avoid the offset of your body during the kicking movements, a track and/or a research assistant, positioned after the chair, offered stability to infant, keeping them by the scapular waist.

The experiment took about two minutes divided into two conditions: 1) training (T) — holding the ankles of infants, the examiner put the right foot then left foot and, finally, both feet simultaneously, three times in a row in order to raise them to trigger the mobile; at that time, the mobile revolved and emitted a children's music with the goal of stimulating the movement taught; 2) Observation (O) — baby positioned in supine for one minute on the examination table, and, during the kicks they could raise the panel with their feet and throw the móbile

The images gets to the computer by a image capture card, using the software Studio 9.1, in AVI format files. Kicking movements were considered every time the baby made some hip movement and knee extension of one or both lower limbs toward the panel. The beginning of the kick movement was established as being the table that showed the first displacement of the markers placed in the trochanter of the femur and lateral malleolus.

The images in Dvideow 6.3 system provides, as a result, the X, Y, and Z coordinates of each marker in each frame of motion analyzed (Figure 3).

After this, we used the program Matlab 6.1 to filter and process this data. A filter of the type digital 4th order Butterworth, with cut off of 6 Hz was applied to the movements coordinates.

The calculation of angular variation of hip, knee and ankle, set to the angles of the hip, knee and ankle were verified from the start till the end.

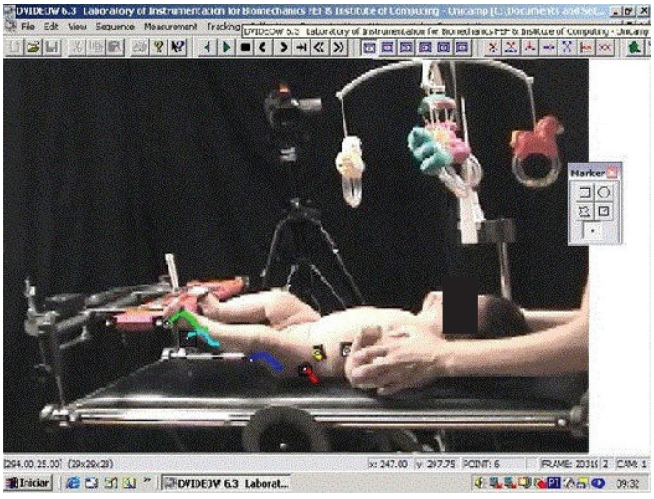

Figure 3. 6.3 Dvideow System Interface and tracking of markers

RESULTS AND DISCUSSION

Accuracy testing of both calibration systems we obtained a 7 mm margin of error for the system 1, while for the system 2, the error was of 2 mm. This result is justified because the system 2 provided a greater number of markers with known calibration volume measures, which ensured greater accuracy in the movement reconstruction. Other studies have demonstrated accuracy of 1 mm[10] and smaller than 3 mm[21], what demonstrates that our system accuracy is compatible with the work carried out

by other authors using other systems. Both lead cones used in the two systems, even though they have different weights (50 g in system 1 and 400 g in system 2), were efficient to serve the purpose of keeping the wires stretched and stabilised during the system calibration.

According to the two other studies conducted in our laboratory using the Dvideow system, it was found that the use of three cameras is suitable for the analysis of kinematics may have manual range[15] and brain-vision coordination[16], but not for studies of infant kicks. In configuration 1, camera one, positioned up at the table, did not allow that we could see all the markers, especially when the baby was doing the hip extension with lateral rotation, damaging the automatic tracking of points during the examination by the Dvideow. In this way, to the study of kicks kinematics, four cameras were required; being arranged two on each side of the examination table, forming an angle of 120° to each other, the markers of the trunk and lower limb infant were seen by two cameras simultaneously, requirement for three-dimensional reconstruction.

The age of infants was also important in kicks observation, because since newborn to four months the kicks are frequent. In the fifth and sixth month, few kick behaviors were observed, because the infants have shown greater interest in bringing the feet to mouth and roll. In the literature, we note that several studies have been conducted in order to observe the kicks in the first months[12,23,24] and a smaller amount has been done to verify this behavior after the fifth month[25].

The 0.5 cm diameter markers reflected properly for viewing on Dvideow system, as long as we use Illuminators in the room. The markes position was adequate and allowed to check the angular variation of the hip, knee and ankle during the kicks. This angular variation is illustrated in Figure 4 for infants with 1, 2, 3 and 4 months.

About fixing the infant children to the examination table, we realized that using the band at the the thorax was a research limitation, because when

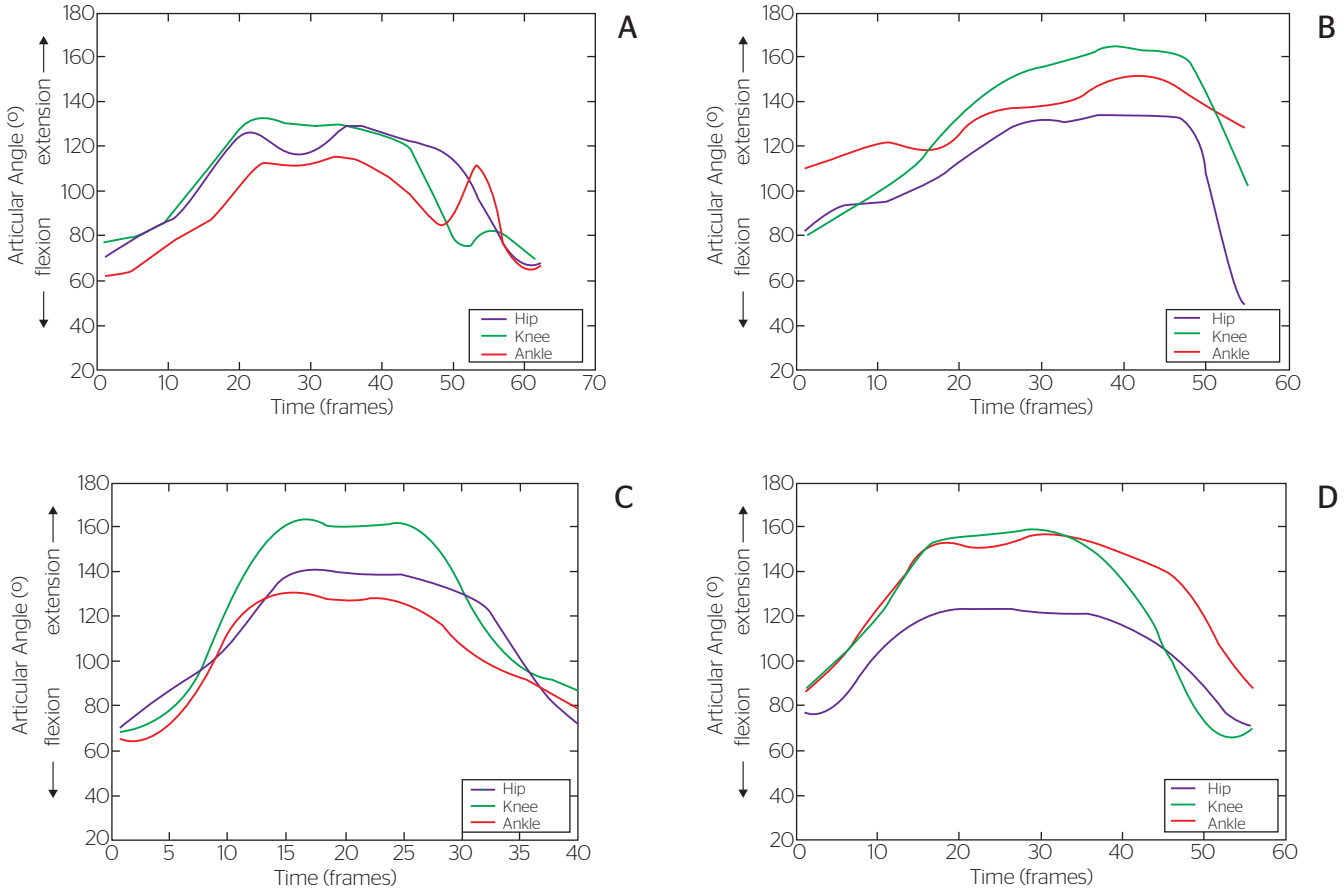

Figure 4. Angular variations of hip, knee and ankle during a kick. (A) one month old infant; (B) two months old infant; (C) three months old; (D) four-month-old infant

the baby touched the panel with his feet, he could boost up, being with the band, and the position was compromised. Besides, the band at the infant's chest made it difficult to see the marker positioned on the trunk. To solve this problem, an examiner stabilized the infant by shoulder girdle.

We also realized that several studies have been conducted to investigate the kicks of infants and the extrinsic or intrinsic factors influence on them. With the apparatus used in this study and the Dvideow system, we were able to verify that this is also possible. We can verify the kicks behavior with the baby kicking in a predetermined time; see how he reacts when we put the panel and the mobile music; check the effect of adding unilateral or bilateral weight; perform studies with infants or neurological injury risk, among other possibilities. In each study, it´s necessary to know exactaly which groups (different ages, infants with intracranial lesions or syndromes, among others) and which variables (frequency, duration, kicking feet, speed preference, among others) are analyzed. A unique feature of our study with infants kicks is that we can measure the feet trajectory and compares it with the shortest distance that the foot could go through. This date was used earlier in the manual range[3] and has not been observed in studies that analyzed infants kicks.

CONCLUSION

The whole method was suitable for the kinematic analysis of infants kicks. The markers and cameras position and the variables studied made it easier to understand the kicks. The use of the Dvideow system to perform the kinematic analysis of infant kicks proved to be appropriate and feasible, since this system is accessible, low-cost and user-friendly for researchers. Also, as it requires only that markers are set at specific points, allows the infants to have freedom of movement.

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