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OBJECTIFICATION OF MOTOR DISORDERS IN CHILDREN WITH CEREBRAL PALSY: WHAT WE KNOW SO FAR

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This study provides an overview of the recent literature regarding the assessment methods of the functional state of the locomotor system in children with cerebral palsy. The objective methods of quantitative assessment of motor disorders in cerebral palsy are presented, including the measurement of stability, biomechanical assessment of walking, and video analysis of movements. The influence of the cognitive load on the ability to maintain the vertical posture in children with cerebral palsy as well as the changes in the stability of the vertical posture with closed eyes were observed. Changes in the walking parameters with an increase in the speed were also recorded in children with cerebral palsy. Methods that assess hand motion in children with cerebral palsy include tests involving the moving of objects, tests for speed assessment in joint movements, and video analysis of motions.
The methods and tests for such an evaluation require to be valid and reliable, allowing an objective assessment of the severity of motor disorders in cerebral palsy.

Keywords: infantile cerebral palsy; walking biomechanics; stabilometry; assessment of upper limb motor skills; video analysis of movement.

ОБЪЕКТИВИЗАЦИЯ ДВИГАТЕЛЬНЫХ НАРУШЕНИЙ У ДЕТЕЙ С ЦЕРЕБРАЛЬНЫМ ПАРАЛИЧОМ: СОСТОЯНИЕ ВОПРОСА

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В статье представлен обзор современных литературных источников по методам оценки функционального состояния локомоторной системы детей с церебральным параличом. Приведены объективные методы количественной оценки двигательных нарушений при детском церебральном параличе (ДЦП), к которым относятся стабилометрия, биомеханические исследования ходьбы, видеоанализ движений. Описано влияние когнитивной нагрузки на способность к поддержанию вертикальной позы у детей с ДЦП, а также изменение устойчивости вертикальной позы с закрытыми глазами. Отмечено изменение параметров ходьбы с возрастанием ее скорости у детей с ДЦП.
К методам, оценивающим моторику кисти у детей с церебральным параличом, можно отнести тесты с перемещением предметов, тесты на скорость движений в суставах и видеоанализ движений.
Используемые методы и тесты должны иметь доказанную валидность и надежность, что позволит объективно оценивать степень выраженности двигательных нарушений при детском церебральном параличе.

Ключевые слова: детский церебральный паралич; биомеханика ходьбы; стабилометрия; оценка моторики верхних конечностей; видеоанализ движения.

Infantile cerebral palsy (ICP) is a term that includes several types of motor disorders. The main clinical manifestations of cerebral palsy are hyperkinesis, muscle paresis, and impaired coordination. In addition to motor disorders, most cases involve violations of the psyche, speech, sight, hearing, etc. [1]. Disturbances in motor functions are partially responsive to functional correction via physical rehabilitation. Rehabilitation programs in such children should be developed considering their rehabilitation potential and adaptation as well as compensatory reserves. Assessment of motor disorders in cerebral palsy is often conducted using scales [2–4]. However, such an assessment

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is highly subjective. An objective assessment of the biomechanical disturbances in children with cerebral palsy is crucial. The reliability of these studies should be ensured by confirming that they meet the standard requirements for measurement instruments and the conditions for their use; the main attributes are the reliability and validity of the test or measurement [5].

The methods of objectification that enable quantitative assessment of motor disorders in cerebral palsy include stabilometry, biomechanical studies of walking, video analysis of movements, and standardized valid tests for motor upper limb evaluation.

This review **aimed** to analyze the studies conducted on the modern methods of quantitative assessment of motor disorders in children with cerebral palsy.

1. Stabilometric assessment of the stability of the vertical posture

The stability of the vertical posture depends on the postural control, that is, on the ability to control the position of one's body in space to achieve the necessary orientation and stability [6]. Several trials have investigated the stability of the vertical posture in children with cerebral palsy [7–13]. For studies of postural stability, dynamometric platforms are most commonly used; they are used to study the moments of forces during walking [14], the amplitude of the reaction force of the support [8, 9], and the evaluation of the trajectory of displacement of the pressure center (PC) for a certain period of time [10–13]. The most informative method for studying postural control of a vertical posture is the study of the change in the position of the total center of mass (TCM) when standing, using the stabilometry method [6]. In order to conduct stabilometric research with an American feet placement, the patient is asked to stand with both feet on the stabiloplatform, set the feet in parallel, place the arms freely along the body, keep the head straight, and look straight ahead [15]. A stabilometric study is conducted to record parameters, such as the length of the statokinesiogram (the path of the center of pressure during the stabilometric study), the velocity of the center of pressure, the area of the statokinesiogram, and the frequency of oscillations in the frontal and sagittal planes [16].

As a rule, the stability of the vertical posture in the standing position is assessed only for children with mild or average severity of violations because the children need to be able to perform the necessary tasks without exterior help. The severity of impairment is conveniently assessed using the Gross Motor Function Classification System (GMFCS) [3]. We are in agreement with the researchers who believe that when studying postural control, the state of the child's cognitive functions also must be considered because it may aid the understanding of the effect of cognitive impairment on the stability of the vertical posture and increase the informative value of the study. In addition, one of the most important factors in postural control is the presence of a reverse visual or proprioceptive communication.

Several studies that have studied postural control have shown that children with cerebral palsy who are able to stand and walk independently exhibit worsening of balance during immobile standing compared to healthy children [6]. However, not all children with cerebral palsy showed similar changes. One study revealed that among children with spastic diplegia, the majority showed normal balance indicators in the standing position [17].

Several studies were conducted to assess the effect of visual [18, 19] and proprioceptive manipulations on the stability of the vertical posture [20]. It is assumed that the best predictor of motor function improvement is the ability to maintain the stability of a vertical posture with closed eyes because children with cerebral palsy mainly use visual information to compensate for their musculoskeletal and neuromotor dysfunctions [21]. In children with cerebral palsy, a greater shift in the TCM with closed eyes was observed in comparison with that in healthy children [17]. Visual deprivation also negatively affected the ability to maintain balance [22]. Thus, in most children with cerebral palsy, visual information is an important factor for maintaining postural control.

M. Schmid et al. studied the effect of cognitive loading on postural control in children [23]. This study involved 50 children (9 years old) who were divided into groups, depending on the severity of neurologic symptoms [24]. All children performed two tests of 60 s each, with and without cognitive load. The cognitive load was that the children had to countdown with a step of 2. During stabilographic examination of the patients, twelve parameters were recorded. The findings showed that when the child performed countdown tasks, the speed and the path of movement of the TCM significantly increased, with violations observed both in the sagittal and frontal planes. These data confirmed the hypothesis regarding the influence of cognitive processes on the ability to maintain a vertical posture in children with cerebral palsy [23].

D. Reilly et al. also evaluated the effect of cognitive loading on the ability to maintain vertical posture in children with cerebral palsy when performing cognitive tasks [25]. The comparison was conducted with a group of healthy children. After the sound signal was given, the child standing on the dynamometer platform was shown an image of multi-colored figures (squares, hearts, or stars) for 300 ms. Thereafter, the screen displayed a completely gray colored image for 5 s. Then, the child was shown images of the figures again; however, their color did not coincide with the colors of the figures shown earlier (E. Vogel's technique, as modified by the authors of the article [26]). These steps were then repeated. The patients were required to respond with "yes" or "no" for whether the colors of the displayed figures coincided. Each test lasted 38 s. The number of correct answers was evaluated. During this study period, they observed that when children with cerebral palsy performed a task, there was a significant deterioration in the stability of the vertical posture in comparison with that in healthy children [25]. Thus, they had a higher rate of displacement of the TCM in the sagittal plane ($p = 0.001$). There was a much larger path of displacement of the TCM in the frontal plane ($p = 0.006$) with increased movement speed of the TCM in the frontal plane ($p = 0.022$) than the healthy children [7]. This study showed that postural control is significantly impaired in patients with cerebral palsy when they perform tasks requiring the participation of visual memory and attention. In general, it appears that the maintenance of a vertical posture is less automated in children with cerebral palsy than in healthy children [27, 28].

2. Biomechanical assessment of walking

Several studies have investigated the gait biomechanics of children with cerebral palsy [29–33]. The most common methods for assessing the gait biomechanics are subgraphic studies and studies of angular characteristics using the motion analysis method. The indicators of walking largely depend on age. Xin Wang et al. assessed the gait of 20 children with cerebral palsy from the age of 3–6 y and compared their walking rates to those of a group of 200 healthy children [34]. All children were divided into four age groups (50 healthy children and 5 children with cerebral palsy were included in each age group). The study showed that with increasing age, the time of single support also increased. The cycle of single support in children aged 3 y was 38% of the step cycle. This ratio stabilized at 40% in children > 3 y old, close to that in adults in whom this parameter ranges from 35%–40%. However, the time of transfer in children with cerebral palsy was approximately 30%, much lower than normal. The support phase in healthy children at the age of 3 y was approximately 63%, comparable to similar indicators in adults. The length of the support phase in children with cerebral palsy was significantly higher than normal, and amounted to 70% of the step cycle. The phase of the double support decreased with age and reached values similar to those of adults. The support phase in 3-year-old children with cerebral palsy was 34%, close to the norm for children aged 1 y whose double support phase was 28.47%. The phase of double support in children with cerebral palsy was 13.5% higher than in healthy children and 10% higher than in adults. Moreover, the length, width, and height of the step were estimated. It was established that the relationship between the length and height of the step can most fully describe the ability to walk in children with cerebral palsy. In the course of work, it was shown that the ratio between the length and height of the step in children with cerebral palsy was 0.16, significantly lower than in healthy children of the same age (0.41–0.61). The width of the step is the distance between the middle of the arch of both feet during walking and is an important factor for measuring transverse stability. The normal width of the step is 5–8 cm and decreases with increasing age [35–39]. The average step width in children with cerebral palsy was 11.69 cm, corresponding to the parameters of a 1-year-old healthy child [34].

In addition, during this study it was revealed that the angle of flexion in the hip joint in children with cerebral palsy significantly differed from that in healthy children during the contact of the foot of the support surface and to the phase of its loading. The angle of flexion in the hip joint was so great that it remained unchanged during the entire phase of foot extension. Further, the angle of flexion in the hip joint on the affected side increased slightly from the beginning of the transfer phase to the time of foot extension. The index of the angle in the hip joint in children with cerebral palsy was significantly lower than the lowest value in healthy individuals [34]. The authors also revealed a change in the angular indices in the knee and ankle joints in children with cerebral palsy; this was explained from the position of compensation for muscle spasticity. Thus, the angle in the knee joint of the affected leg remained unchanged from the beginning of the phase of touching the surface till the completion of the phase of its loading. The angle of flexion in the ankle joint remained unchanged during the entire walking cycle.

The angle of body bending also changed significantly. Children with cerebral palsy were unable to bend the hip; for compensation, they had to strain the abdominal muscles and bend the torso forward. Thus, the children had to bend the body forward to compensate for the decreased strength of the hip flexors and the violation of the detachment of the limb from the floor. The reverse movement of the body led to further bending of the hip joints.

In addition, in children with cerebral palsy, angle of the feet placement during walking was changed. This angle is measured between the foot and the centerline of movement for each leg and is normally approximately 15° [35, 36]. This angle is a consequence of the external rotation of the lower limb joint that occurs secondary to flexion of the thigh and rotation of the shin bones. If the thigh and shin bones do not rotate normally, the angle of the foot placement also changes [14, 40, 41]. During this study, a large difference was observed in this parameter between healthy children and children with cerebral palsy, in whom this angle was approximately 5°. However, the changes that affected the equilibrium point were not significant. The displacement of the vertical center of gravity in children with cerebral palsy was 0.15 m, while in healthy children it was approximately 0.13 m [34]. Special aspects of the biomechanical structure of walking in children with cerebral palsy are also represented by a change in the time characteristic of the step caused by increased duration of support phase and reduced duration of the mobile phase, flexion of the lower extremities during the step cycle, and restriction of movements in the main joints of the legs. These changes in the structure of walking are attributable to the action of pathological factors that contributed to the formation of an incorrect posture of the patient's body, while the transformation of the innervation stereotype of walking is predominantly adaptive [29].

The biomechanical parameters of gait in children with cerebral palsy may be significantly affected by the walking speed. K. Kane et al. evaluated the results of temporary tests of walking of 16 children with cerebral palsy at 7–9 y of age and compared them with those in healthy children [42]. The researchers selected a 10-meter walk test, the "Stand up and Go" test, an obstacle test, and a border test [42, 43]. The criteria for inclusion in this study were age 2–13 years, the ability to walk at least 14 m independently, and the absence of additional disorders that affect balance or the ability to walk. All tests were performed at two speeds, arbitrary and fast. This study found that healthy children completed all the tests at a much higher rate, with the greatest difference observed during the performance of the obstacle test and border test. A significant difference was observed between the groups of healthy subjects and patients during the performance of tasks at a fast rate.

New opportunities for studying walking in children with cerebral palsy are provided using the method of video analysis of movements. Thus, T. Terjesen et al. studied the change in gait biomechanics in children with cerebral palsy after the surgery [44]. As a method of assessing the effectiveness of the surgery, three-dimensional (3D) video analysis of gait was performed; it was performed before the surgery, one year after the surgery, and five years after the surgery. As a measurement tool, the Vicon motion video analysis system with six cameras and two dynamometer platforms was used. Children performed at least 3 passes barefoot at an arbitrary speed along a 10-m track. For the analysis, the mean values obtained from all three passes were used. In addition to individual kinematic parameters, the total walking statistic was additionally estimated using a Gait Profile Score (GPS) [4] that provides a single index of the overall walking quality based on nine kinematic variables (angular pelvic and hip joint values in 3 planes, the angular indices of the knee and ankle joints in the sagittal plane, and the movement of the foot). It was found that the walking function improved compared to the preoperative level in the first year after the surgery for the 5- and 50-m distance; however, the difference in the distance of 500 m was no longer significant. The result was significantly improved for all three distances 5 y postoperatively.

The method of video analysis of movements was used by N.Yu. Titarenko et al. for assessing the effectiveness of rehabilitation in children with cerebral palsy [45]. The study involved 61 children with cerebral palsy in the form of spastic diplegia, aged 8–12 y. The children were divided into two groups to investigate the effectiveness of two different regimens of the Graviton device settings in rehabilitation (standard settings and tuning with aggravated pathological posture). To assess the biomechanics of gait, children were asked to walk barefoot along the path; in addition, two-dimensional (2D) video recording was performed in the sagittal plane [46]. In children with cerebral palsy, the touch of the surface occurs with the anterior part of the foot, while there is no biomechanical damping in the knee joint, indicating a gross violation of the buffer properties of the supporting limb, a potential cause of dysplastic arthrosis in patients with cerebral palsy. Before rehabilitation, there were no significant differences in the biomechanical indicators of walking in children from both groups. After the rehabilitation, the cinematograms of both groups were reliably approaching the norm ($p < 0.001$). However, in the second group, significantly more normalized angular displacement trajectories were recorded ($p < 0.05$).

Thus, the evaluation of gait biomechanics allows objectification of the degree and nature of severity of motor disorders in cerebral palsy and helps evaluate the results of the rehabilitation interventions.

3. Assessment of general and fine motor skills of the upper extremities in children with cerebral palsy

In the structure of motor defect in children with cerebral palsy, the disorders in the hand functions are crucial. In some cases, they hinder house, school, and labor adaptations, making it impossible to use several orthopedic adaptations necessary for the development of walking.

The severity of the lesions in the upper limbs varies with different forms of cerebral palsy. The function of the upper extremities in the hyperkinetic and hemiparetic forms of paralysis is most severely violated. In the later stages, although half of the body is affected, the degree of violation of the upper limb functions is often severe, complicating the process of forming the manipulative activity and self-service skills.

Evaluation methods

Several scales are available that assess the movements of the upper limb and the hand in children with cerebral palsy in points: the Manual Ability Classification System (MACS), the Bimanual Fine Motor Function (BFMF) scale, the scale of Quality of Upper Extremity Skills Testy (QUEST). The disadvantage of using the scales is that it performs subjective assessment of motor disorders in patients with cerebral palsy, requires a study with a long duration, and warrants voluntary consent from the study participants; in addition, the use of certain scales require special equipment or computer programs as well as skills of use and licenses. Therefore, methods that objectively assess the movements of the upper extremities in these children are very important.

The objectification methods that evaluate hand motility in children with cerebral palsy include tests with moving objects, tests for the speed of joint movements, graphic tests, and tests that involve video analysis of movements.

Tests with objects

The Box and Block Test (BBT, English). The BBT test, developed more than 30 y previously, is a quick tentative method to assess the dexterity of the hands of adults and children with various forms of pathology [47]. The equipment includes an open box with a partition in the middle, 150 wooden cubes, and a stopwatch. The box is placed on an ordinary table, the testee sits on a chair of usual height in front of the table. The number of cubes that the subject can capture with a hand within 60 s, transfer through the partition, and put in the next compartment of the box is calculated. First, the dominant and then the non-dominant hand are examined. For adults > 20 y old and children aged 6–19 y, normative data are available [48]. However, few studies have investigated the use of BBT in cases of cerebral palsy. Thus, C.L. Ferre et al. examined the effectiveness of intensive home bimanual training under the supervision of a tutor in children with unilateral spastic cerebral palsy using the BBT method [49]. The results confirmed a significant improvement in the time for the test in children with cerebral palsy than in the randomized control group. Thus, BBT can be used for assessing the efficiency of rehabilitation interventions in children with cerebral palsy.

The Nine-hole Peg Test (9-NHT). This test assesses the dexterity of the subject's fingers by recording the time that he/she takes to place the pegs in the holes intended for them [50]. The equipment includes 9 wooden pegs (pins) of 32 mm length and 9 mm diameter; a plate with 9 holes of 0 mm diameter and 15 mm depth, arranged in 3 rows with 3 holes each, 15 mm from each other.

Initially, the test was used for diagnosing the hand function in patients with multiple sclerosis. Thereafter, J.L. Poole et al. presented the results of conducting the test for 406 healthy children aged 4–19 years with an estimate of the accuracy and timing of its performance [51]. Thus, the time limits for performing the test were obtained, depending on the age, sex, and hand dominance [51]. The obtained normative data can be used for estimating the motor function of the hand in children with various disorders, including cerebral palsy.

M. Valenza et al. examined the motor functions in children with cerebral palsy, using a 9-NHT [52]. This prospective study was conducted during November 2013 to October 2016 and involved children of both sexes aged 6–10 y with cerebral palsy who are able to attend school. Children with severe cognitive impairment were not included. The time taken and accuracy of the task were assessed. The results are yet to be published.

The Jebsen-Taylor Test of the Hand Function (JTHF) was originally developed to assess the motor abilities and hand dexterity of adults with various forms of pathology [53]. It includes 7 tasks performed with one hand, such as writing on the pattern of the sentence of 24 letters, turning cards sized 3 × 5 inches, collecting and moving small items (coins or bottle caps) into a container, placing checkers in a column, simulating feeding with a teaspoonful and beans, as well as displacing large, light (an empty jar), and heavy (heavy jar) items. A standardized set of items is provided for the task. Using a stopwatch, the test time is recorded. The score for each tasks is equal to the execution time in seconds, and the total score of the JTHF is the sum of these estimates (lower scores correspond to greater preservation of hand function; the quality of tasks is not evaluated). M.B. Brandão noted that intensive bimanual daily training of 5 mo significantly improved the hand accuracy in a group of children with cerebral palsy and in the control group [54].

The Assisting Hand Assessment (AHA) enables the measurement and description of how children with cerebral palsy (aged 18 mo to 12 y) with unilateral damage to the upper limb use injured and intact hands in a bimanual game [55]. AHA evaluates the ability to handle objects while playing under natural conditions. The test uses 22 objects that the child must take, hold, and put. A 15-min game session is evaluated. Toys from the AHA test kit are interesting and provoke the use of both hands during gameplay. The test quality is assessed on a 4-point scale (1: unable to perform and 4: performs effectively). The points range from 22–88. There are two versions of the test: 1) Small Kids AHA is designed for children aged 18 mo to 5 y, while 2) School Kids AHA is designed for children aged 6–12 y. The reliability and validity of the tests in relation to each other are described by L. Krumlinde-Sundholm [56].

The pyramid test, developed by E.S. Nikitina, involves the grasping of objects and the possibility of their location in a certain sequence [57]. The child is required to build a pyramid of 5 rings placed on a vertical rod. The time of the test is recorded. The purpose of the test is to assess the motor skills and abilities, the accuracy of grasping the object, and the sequence of actions.

Tests on the speed of movement in the hand joints

Tests for the speed of movements in the joints can be used for functional evaluation of the capabilities of the upper limbs.

Flexion and extension in the radiocarpal joint are evaluated as follows. The child, sitting on a chair, hangs his hands from the armrests and produces an alternate extension of the right and left hand. In total, 10 movements are performed at an arbitrary speed. For a healthy child, the norm is 12–15 s. During task execution, the compensatory movements, intensity of hyperkinesia, etc. are registered

Forearm supination and pronation is assessed by the ability to perform 10 movements of the forearm at an arbitrary speed. For a healthy child, the norm is 40–50 s. The patient should note the degree of fatigue; in addition, attention is paid to the stiffness of the shoulder girdle muscles.

To assess the manipulative function of the hand, the "Ring" test is used. For this, it is necessary to alternately contrapose the first finger to all the other fingers at an arbitrary speed. The test time is normally 6–7 s, and the contraposition of the first finger to the second and third is easier than to the fourth and fifth.

Various test tasks in the form of lacing, pleaching "pigtails" from a thread of yarn, fastening-unbuttoning a number of buttons, and others can also be used with children. The time taken to complete the test is recorded [58].

Graphic tests

Graphic tests are used to diagnose the level of mental development of children and their violations. However, when performing these tests, it is crucial to evaluate the complexly coordinated movements of the hands and fingers of a child. Assessment of the style of drawing according to age is based on the use of rank scales. As an example, we can cite the widely known Kern-Jirasek test of the school maturity that is intended for children aged 3–14 y and consists of 3 tasks. The first task involves drawing a male figure from memory, the second is copying letters, and the third is copying a group of points. The result of each task is estimated on a 5-point system (1 being the highest and 5 the lowest); the total score is then calculated. The development of children who received 3–6 points is considered above average, that of those with 7–11 points is considered average, and that of those with 12–15 points is considered below the norm [59].

Nominative scales include many qualitative features of the image, each of which is rated on a scale of 0–1 points, such as in the tests of "Man picking an apple from a tree" or "Draw a person" by Gudinaf-Harris [60].

The tests are based either on the knowledge of age stages in the development of drawing styles or on the patterns of progression of particular characteristics of images associated with the age development of individual cognitive abilities [61], such as the visual perception test "Bender-Gestalt-test" [62]. The subject is asked to copy 9 original figures of Wertheimer (gestalt). Unlimited time is provided for the task. The test is simple, easy to use, highly reliable, and characterizes non-verbal mental capacity and perceptual motor coordination.

Graphical tests are widely used in practice by Russian psychologists; however, these are not validated because of their deceptive diagnostic simplicity and great attractiveness for children [61]. The choice of a methodical range largely depends on the "capabilities" of the examined child with cerebral palsy and on his/her ability to perform certain test tasks. It should be remembered that even if the state of a child with cerebral palsy enables him/her to perform the test, as a rule, correction of time constraints is required, as stipulated in the methodology.

Video analysis of movements

The most accurate method for studying human locomotion is the biomechanical analysis of video images of movements. In the last decade, increasing number of studies has used 2D and 3D analysis for evaluating upper limb movements in children with cerebral palsy.

F. Gaillard et al. studied the relationship between the violations of the kinematics of the affected upper limb and the efficiency of its movements while performing bimanual tasks. Total 23 children with cerebral palsy were examined (mean age 11.9 ± 2.7 years). A standardized 3D analysis protocol was used for evaluating the movements of the upper limb, comprising several tasks for performing specific functionally significant movements. The total kinetic indices were calculated as per the Jasper method for assessing the severity of upper limb movements in children with cerebral palsy. The obtained results were compared with the data of the norm group, consisting 28 healthy children (mean age 11.8 ± 2.2 years). A significant correlation was revealed from the evaluation of the angles of flexion of the wrist, elbow, and pronation of the hand ($r = -0.85$; $r = -0.61$; $r = -0.47$, respectively) [63].

M.C. Klotz et al. studied the deviations in the motion of the upper limb in children with unilateral cerebral palsy using 3D registration of movements. The study included 16 children with spastic unilateral cerebral palsy who were compared to 17 healthy adolescents. The time and biomechanical range of movements were correlated and compared when performing 6 daily tasks with one or both hands. Restriction of the range of movements was most pronounced in the forearm. The 3D record enabled them to obtain more detailed information regarding the deviations from the norm of the parameters of upper limb motions in children with cerebral palsy compared to that in healthy subjects [64].

For the objectification of upper limb movements in children with cerebral palsy when sorting objects, Y. Quijano-Gonzalez et al. used video analysis. Children were divided into two groups (with cerebral palsy and healthy) and asked to place geometric objects in sorting boxes and remove them from boxes. During this, their wrist movements were recorded using a video analysis system. The time of the task was estimated. The smoothness of movements serves as an effective tool for identifying the affected and healthy subjects, and differences in the quantitative indicators indicate an affected and intact limb in children with cerebral palsy [65].

Conclusion

Thus, a review of the literature shows that in clinical practice worldwide, various methods are used for assessing the functional state of children with cerebral palsy; these enable the quantification of the degree of disturbance of locomotor functions. Stabilometry as well as 2D and 3D video analysis of walking movements are the most suitable methods. The fine motor skills of the hand are assessed using the 9-NHT.

These methods are well reproducible and must be performed strictly as per protocol using certified equipment to ensure accurate data. They should be used in research and in clinical practice.

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