

Foot kinematics in gait of children with cerebral palsy (CP)

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Cerebral palsy (CP) is a developmental disorder of motor, psychological and emotional functions. Its most typical symptom is a walking disorder. The aim of this study was to analyze children's walking abilities based on basic kinematic parameters. In this research, the analysis of a three-dimensional kinematical movement is used to record the right and left parts of the child's body. The walking skills of two CP children are described. For locomotion analysis, the angular displacements in the right and left knees and ankles and foot distortion in both support and swing phases of the walk were chosen. The kinematic parameters can be helpful in the diagnosis and allow physiotherapists to suggest what exercise program should be developed in order to improve the habit of walking.

Key words: cerebral palsy, walk, 3D kinematics analysis

1. Introduction

Cerebral palsy (CP) is a developmental disorder of motor, psychological and emotional functions [1]. The damage to a central nervous system is caused by various etiological factors. The most typical symptoms of CP are the disorders of movement activities of various degrees and different locations. These are most often contractures of limbs and trunk, mostly of spastic type, balance disorders and motor hyperactivity. A special disorder is the restriction of walking efficiency or a child's inability to walk on its own. The lack of control is especially serious within the ankle bone joint and foot. The pathological mechanism of the foot movement is mostly visible in the foot support phase and it results from the foot structural deformation and/or contracture of muscles. As regards the foot in its support phase, the literature differentiates between the so-called rockers [2], i.e. heel rocker,

ankle rocker and forefoot rocker. A child suffering from CP and experiencing the contractures of lower limb muscles often walks on its toes and distorts the foot in the inward direction. In such cases, doctors can apply appropriate rehabilitation treatment or surgical operation consisting in TAL (Tendon-Achilles Lengthening). The operation does not always bring the expected results [3].

Therefore, the aim of this study was to analyse the foot kinematics and its influence of knee joint movement, paying a special attention to the so-called rockers occurring in the foot-support phase.

2. Experimental procedures

The examinations of children with CP were carried out in the Centre for Children with Cerebral Palsy in Mikoszew. The locomotion of children with

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CP is highly diversified and it is difficult to present and describe it for a given group of children. That is why this study is restricted to the description of a foot movement and its influence on knee joint movement in two children. One child, named 1/MJ/02, was a 12-year old girl with infantile cerebral palsy, spastic diplegia, flexion contracture of the knee joint, irreducible joint contracture, left-sided scoliosis, paraparesis and gait with flexed knees and foot distortion [4]. The other child, named 29/NK/06, was a 14-year old boy with infantile cerebral palsy, very low spastic diplegia and able to walk unaided [4].

The foot movement was analysed in three-dimensional space. Four cameras were installed in the corners of the room of 15 m × 20 m dimensions. The cameras were set to record 6 walk cycles. Next, the film was digitalised and basic kinematical parameters calculated with the use of SIMI software.

The foot movement mechanism is characterized by three rockers described by PERRY [2], namely a heel rocker, ankle rocker and forefoot rocker. The contractures of shin muscles and foot deformation interfere with the mechanism. This manifests itself as a restricted movement in ankle bone joint and an accompanying restriction of movement in ankle knee joint and foot distortion.

The foot rockers occurring in the foot-support phase, as described by PERRY [2], are found in the gait of a normal person. These are (figure 1):

1. Heel rocker – from the moment a heel contacts the ground for the first time until the entire foot is put on the ground.
2. Ankle rocker – with the entire foot contacting the ground.
3. Forefoot rocker – from the moment a heel is raised off the ground until toes are raised off the ground.

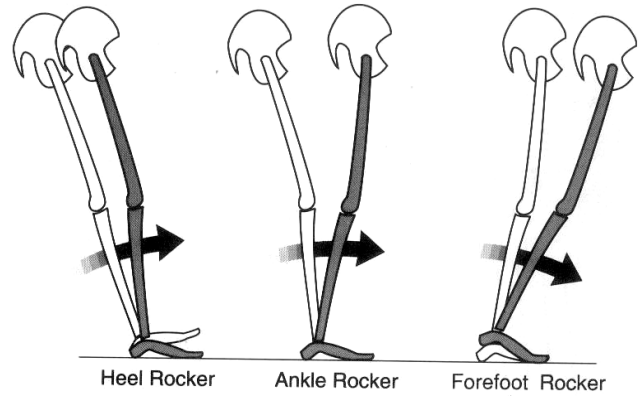


Fig. 1. Progression (arrow) in foot support consisting of three functional rockers: (1) heel rocker, (2) ankle rocker, (3) forefoot rocker by PERRY [2]

3. Result

One of the two children under examination, i.e. the boy 29/NK/06, experienced all the above-mentioned rockers. As far as the girl 1/MJ/02 is concerned, there was no the first rocker in the right lower limb as well as no the first and second rockers in the left lower limb. Figures 2a), 2b), 3a) and 3b) present the movement of knee joints and ankle bone joints in the girl and boy examined. The angle of 0° in the knee joint is the anatomical angle, where the shank and foot are in anatomical position in relation to each other; due to flexion (↓) the knee angle α_k decreases, due to extension (↑) the knee angle α_k increases (figure 5a, b). An ankle joint takes the anatomical position (0°) when the foot is perpendicular to the shank. Dorsal flexion has a positive value ($\alpha_g < 0^\circ$), while plantar flexion has negative

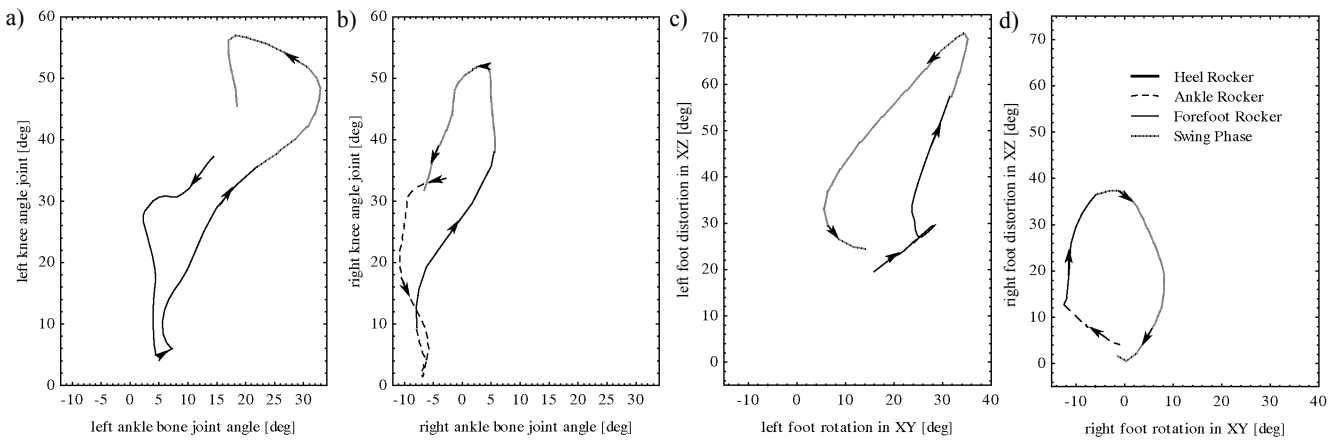


Fig. 2. Movement of feet and knee joints for child 1/MJ/02: a) angular displacement of left knee and left ankle bone joints, b) angular displacement of right knee and right ankle bone joints, c) left foot distortion in transverse and sagittal planes, d) right foot distortion in transverse and sagittal planes

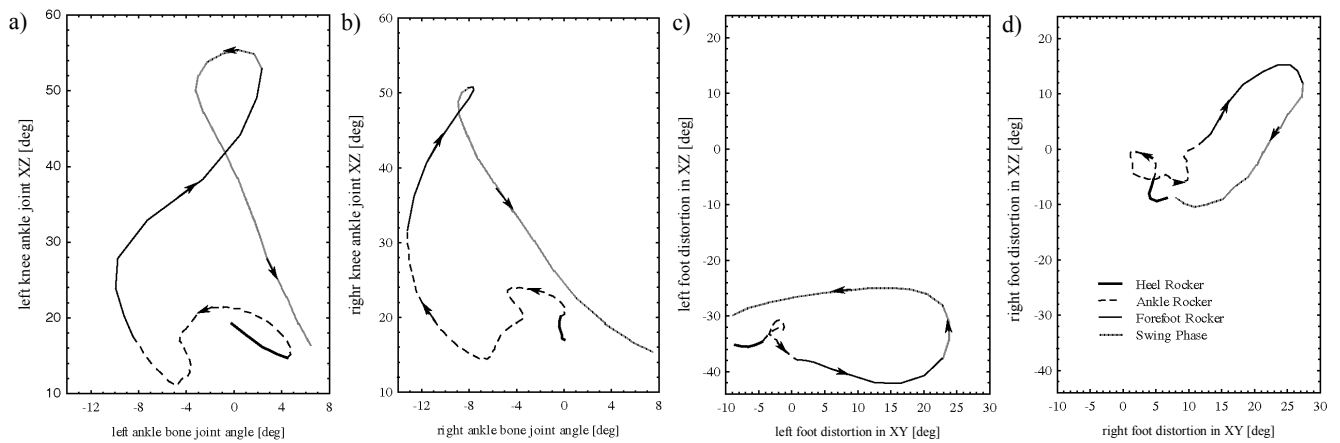


Fig. 3. Movement of feet and knee joints for child 29/NK/06: a) angular displacement of the left knee and left ankle bone joints, b) angular displacement of the right knee and right ankle bone joints, c) left foot distortion in transverse and sagittal planes, d) right foot distortion in transverse and sagittal planes

values ($\alpha_p < 0^\circ$). When the values are positive or negative, but fairly close to 0° , the ankle joint is extended (\uparrow); when they are higher than 0° , the ankle joint is flexed (\downarrow) (figure 5c, d, e).

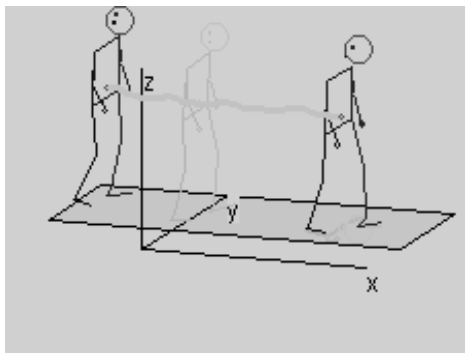


Fig. 4. Stick diagram.

Foot distortion in transverse plane and sagittal plane

The contractures of shank muscles also cause the foot to distort in XZ transverse plane and XY sagittal plane (figure 4). Figures 2c, d and 3c, d present the foot distortion in XZ transverse plane and XY sagittal plane in the children examined.

The angle of the foot twisted in the XZ transverse plane is contained between the long foot axis and the sagittal plane. If the angle takes the value of 0° , the long axis of foot runs along the sagittal plane. Positive values indicated that the foot is distorted inwards, i.e. abnormally. During the support phase, the foot should be distorted outwards by about 5° – 7° and has negative value [5].

The angle of the foot twisted in the XY sagittal plane is contained between the long foot axis and the ground. The angle has the value of 0° , when the entire foot is put on the ground. The angle has a negative

value when heel comes into contact with the ground, whereas it has a positive value when the toes come into contact with the ground [5].

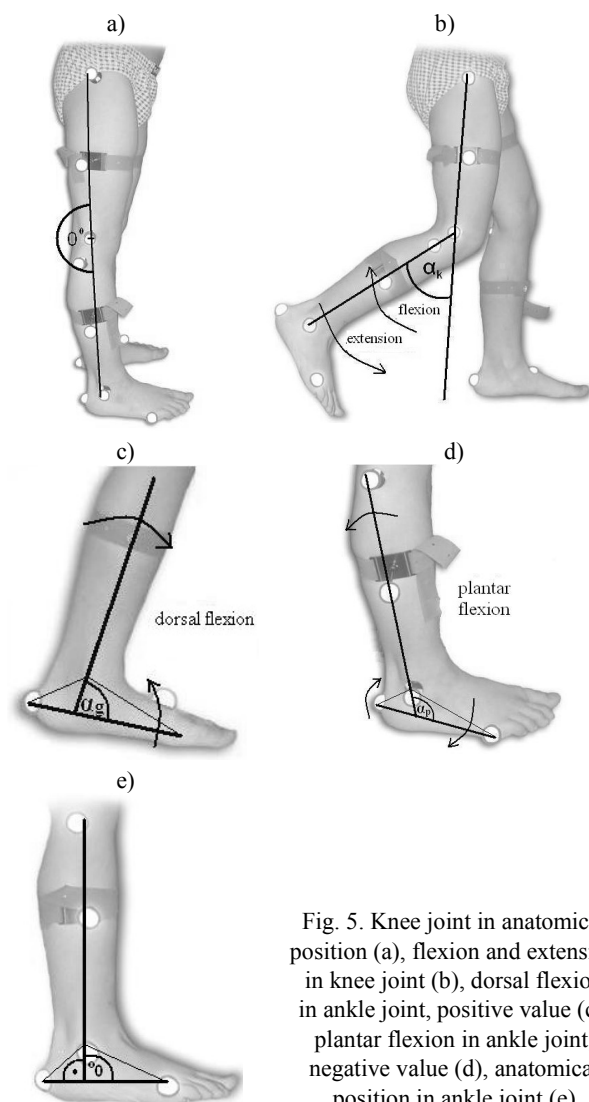


Fig. 5. Knee joint in anatomical position (a), flexion and extension in knee joint (b), dorsal flexion in ankle joint, positive value (c), plantar flexion in ankle joint, negative value (d), anatomical position in ankle joint (e)

4. Discussion of results

The child 1/MJ/02 has a visibly weaker left lower limb, which is presented in figure 2. In the support phase of the limb, the foot is put incorrectly due to contractures of shank muscles and the foot is supported on the toes only (the 3rd rocker). This disorder manifests itself also as an incorrect movement of ankle bone, knee joint and as the asymmetrical movement of the right lower limb. The contractures of the right limb are weaker. The child does not put the foot with its heel on the ground, but she/he puts the entire foot on the ground and pushes off the ground with the toes (the 2nd and 3rd rockers). This is also reflected in the model movement of the knee joint and ankle bone joint in the support phase as in the model described in literature [5]–[8].

The child 29/NK/06 is characterized by a correct movement of knee joints and ankle bone [6], [7]. The order of the occurrence of rockers is also preserved. Figure 3 presents the relation between the angles of knee joints and ankle bone joints for the left and right limbs of the boy 29/NK/06. The mutual dependence of the movements of knee joints and ankle bone joints is symmetrical and complies with the standards described in literature [5]–[7].

Figure 2c and d presents the change in the angle of feet distortion in the XZ transverse plane for the child 1/MJ/02. The girl's left weaker foot is heavily distorted inwards. The right foot is slightly distorted outwards with the distortion angle within the standard values.

The boy 12/KN/06 distorted his feet asymmetrically in the XZ transverse plane, which is presented in figure 3c and d. Apart from the visible asymmetry, none of the feet is put correctly, with the right foot twisted inwards during the entire cycle and the left foot twisted outwards, however, by 20° more than required.

In the girl 1/MJ/02, the angle of the foot twisted in the XY sagittal plane is shown in figure 2c and d. In the case of the right limb, the angle of the support phase approached the value of 0° and it assumed positive values in the case of the second rocker. These are correct values, as the girl starts the support phase using the entire foot, i.e. she starts from the 2nd rocker. As a result of the contracture of shank muscles, the left foot in the support phase touches the ground only with its toes during the entire cycle.

The angle of the foot twisted in the XY sagittal plane for the child 29/NK/06 is presented in figure 3c and d. The boy experienced all of the three rockers, which is reflected in the correct change of XY angle in the support and swing phases.

5. Conclusions

The contracture of lower limb muscles in children with CP results in the incorrect gait motoric functions. This is reflected in unnatural support of the foot on the ground and the child walks on its toes and twists the foot inwards. The gait disorder is also visible in the abnormal cooperation of the foot with knee joint in the support phase. The analysis of location of the foot and knee joint in relation to each other will make it possible to show quantitative differences between the expected and actual functions of the foot. In the process of a child's rehabilitation, such an approach would provide guidelines for physiotherapists to proceed in their treatment, whereas doctors would be provided with pictures and possible indications for TAL surgery.

References

- [1] MICHAŁOWICZ R., *Definicja, obraz kliniczny, podział*, [in:] *Mózgowe porażenie dziecięce*, PZWL, Warszawa, 2001.
- [2] PERRY J., *Gait analysis: Normal and pathological function*, Thorofare, NJ, Slack, 1992.
- [3] GAGE J.R., *The Treatment of Gait Problems in Cerebral Palsy*, Mac Keith Press, Cambridge, 2004.
- [4] KOBEL BUYS K., *Rozpoznanie neurologiczne i kwalifikowanie dzieci do programu*, [in:] T. Bober and K. Kobel Buys, *Mózgowe porażenie dziecięce z doświadczeń trzyletniego programu rehabilitacji*, Studia i Monografie AWF, Wrocław, 2006, 81, 84–92.
- [5] SUTHERLAND D.H., *The development of mature gait*, *Gait and Posture*, 1997, 6, 163–170.
- [6] ÖBERG T., KARSZANIA A., ÖBERG K., *Basic parameters: reference data for normal subjects 10–79 years of age*, *Journal of Rehabilitation Research & Development*, 1993, 30, 210–233.
- [7] KELLY I.P., O'REGAN M., JENKINSON A., O'BRIEN T., *The quality assessment of walking in cerebral palsy*, *Gait & Posture*, 1997, 5, 70–74.
- [8] CRENNAN P., FEDRIZZI E., ANDRUECCI E., FRIGO C., BONO R., *The heel-contact gait pattern of habitual toe walkers*, *Gait & Posture*, 2005, 21, 311–317.