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BIONICS IN PLANNING OF HABILITATION FOR CHILDREN WITH CEREBRAL PALSY

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Abstract: Assessment of integral deficit of muscular and controlling activity (which needs to be compensated by external energy and information) comes down to defining the difference between biomechanical and neurological activity in health and in disease by comparing a set of parameters of chronological age in health with the actual child's chronality parameters. The difference between these values creates the aggregate amount of deficit (Δ) followed by the amount of free time (D) and the amount of external energy (E) necessary for habilitation.

Key words: *bionics, time/energy, habilitation, cerebral palsy.*

I. INTRODUCTION

The process of habilitation of paediatric cerebral palsy is possible only through imperative locomotor activity of a child with the help of external energy and information, i.e., by using a locomotor robot [7]. The First Law of Chronodynamics states that with the help of external energy it is possible to change the chrono density within the local subspace (body), while the amount of the modified chrono density (d) will be equivalent to the amount of energy consumed by the system (ΔE), i.e., $\Delta E = h - d$ [1]. This serves the basis for assessing and planning habilitation of children according to the method that allows for compensation of muscular and controlling activity deficit with the help of external energy [3]. The Second Law of Chronodynamics states that the general internal (X) of the object's system is invariable and is determined by the sum of free (D) time (varies depending of the energy input) and linked (H) time, i.e., $X = D + H$. The subject of this research is determination of the amount of time and energy that are required for habilitation of children with cerebral palsy and cerebrospinal conditions.

II. METHODE AND RESULTS

Assessment of integral deficit of muscular and controlling activity (which needs to be compensated by external energy and information) comes down to defining the difference between biomechanical and neurological activity in health and in disease by comparing a set of parameters of chronological age in health with the actual child's chronality parameters. The difference between these values creates the aggregate amount of deficit (Δ) followed by the amount of free time (D) and the amount of external energy (E) necessary for habilitation.

According to the method suggested by G.Doman [4] the patient's neurological age is determined by two criteria – manual competency and mobility in actual reality and in comparison to those typical for a specific age. The difference Δ_{GD} [in months] between neurological and chronological age serves as quantitative indicator of the deficit of controlling activity. According to the author's method, biomechanical age is determined by several criteria: mass, height, amplitude of flexion-extension angles of the legs, legs shape, and proportions of the body dimensions in the course of growth, which are compared to chronological parameters. The difference Δ_{ED} between biomechanical and chronological age serves as quantitative indicator of the deficit of muscular activity. The overall deficit is determined by adding up the components $\Delta = \Delta_{GD} + \Delta_{ED}$[months] (1)

Table 1. Seven stages in child's life: full spectrum of brain development since birth until controlling functions occur and come into operation (acc. Glenn Doman, 1962)

Stages	Timeframe		Dominating brain stage	Manual competence	Mobility	Time needed by child to reach neurological maturity	Development prospects
1	2		3	4	5	6	7
I	Birth 0 year 0 months	Outgrowing 0.5 m Middle 0.0 m Slowed 2 m	EARLY BRAIN STEM AND SPINAL CORD	Grasping reflex	Arm and leg motions without body movement	1 – 23 months	Superb
II	0 y + 1 m 2.5 months - 5 m	Outgrowing 1 m Middle 2.5 m Slowed 5 m	SPINAL CORD AND EARLY SUBCORTICAL AREAS	Vitally important finger release and unclenching	Crawling upon stomach face down, developing into crossed crawling face down		
III	0 y + 3.5 m 7 months 1 y 2 m	Outgrowing 3.5 m Middle 7 m Slowed 14 m	MIDBRAIN AND SUBCORTICAL AREAS	Prehensile grasping	Hand and knee crawling, developing into twisted crawling on fours		
IV	1 y + 6 m 12 months - 2 y	Outgrowing 6 m Middle 12 m Slowed 24 m	INITIAL CORTEX	Cortical counterposition on one of hands	Walking with arms used in primary balance role, usually at shoulder height or higher		

Stages	Timeframe		Dominating brain stage	Manual competence	Mobility	Time needed by child to reach neurological maturity	Development prospects
V	1 y 6 m + 9 m 18 months - 3 y	Outgrowing 9 m Middle 18 m Slowed 36 m	EARLY CORTEX	Cortical counterposition, two-sided and simultaneous	Walking with arms free of primary balance role	24 – 35 months	Magnificent
VI	3 y + 1 y 6 m 36 months - 6 y	Outgrowing 18 m Middle 36 m Slowed 72 m	PRIMITIVE CORTEX	Both hands functioning, one hand uses acquired experience	Walking and running according to crossed model in full extent	36 – 47 months	Excellent
						48 – 59 months	Good
VII	6 y 0 m + 3 m 72 months - 12 y	Outgrowing 36 m Middle 72 m Slowed 144 m	COMPOUND CORTEX	Hand used for writing in permanent connection with dominating hemisphere	Leg used in role acquired by experience, in permanent connection with dominating hemisphere	60 – 119 months	Proper
						120 – 191 months	Weak
						192 months and more	Currently impossible

Table 2. Six stages in child's life: full spectrum of biomechanics development until occurrence of aimed movements in space (acc. E.Dukenjiev)

Stages	Timeframe		Mass [kg]	Height [cm]	Full amplitude of interlink angles (average for right and left extremity) [°]		
	Years	Year intervals			Ankle joint	Knee joint	Hip joint
II	Birth 0 years	1 - 6 months	2.5 ÷ 4.2 ± 1.2	40.3 ± 4.1	---	---	---
		7 – 12 months	6.17 ÷ 9.7 ± 0.9	80.6 ± 10.3			
II	1 year	1 - 6 months	11.6 ± 0.9	80.1 ± 2.6	23.55 ± 5.63	47.7 ± 5.17	35.45 ± 4.25
		7 – 12 months	13.1 ± 1.2	86.1 ± 2.3	21.9 ± 3.33	51.35 ± 4.37	34.25 ± 5.29
III	2 years	1 - 6 months	13.8 ± 1.9	88.1 ± 2.8	23.2 ± 3.33	53.95 ± 4.48	35.0 ± 5.29
		7 – 12 months	16.6 ± 0.9	97.8 ± 2.9	22.6 ± 3.22	51.6 ± 6.98	34.25 ± 5.52
IV	3 years	1 - 12 months	17.8 ± 1.6	104.8 ± 3.3	24.1 ± 3.78	51.05 ± 3.57	32.8 ± 4.2
V	4 years	1 - 12 months	19.2 ± 1.6	107.2 ± 2.9	22.6 ± 9.99	49.25 ± 3.91	28.65 ± 4.94
VI	5 years	1 - 12 months	22.1 ± 1.3	118.2 ± 7.7	25.0 ± 2.87	52.25 ± 3.56	32.55 ± 4.6
1	**2.1**	**2.2**	**3**	**4**	**5**	**6**	**7**

Table 3. Shape of legs in different periods of child's growth. Leg axis H-H moves laterally

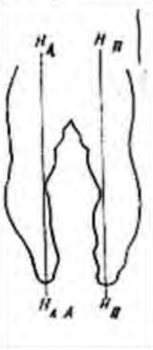
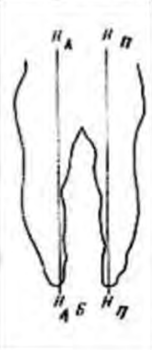
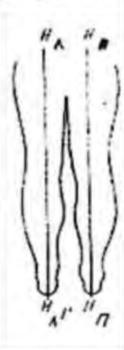
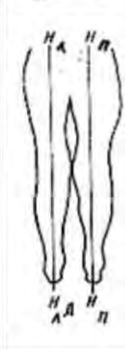
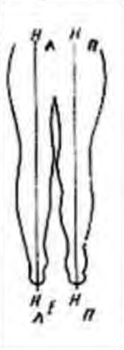
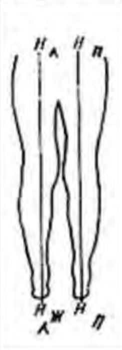
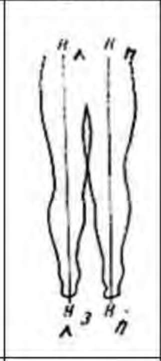
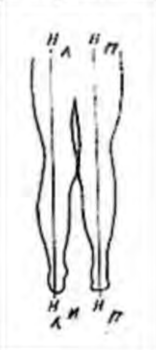
Shape No. 1	Shape No. 2	Shape No. 3	Shape No. 4	Shape No. 5	Shape No. 6	Shape No. 7	Shape No. 8	Shape No. 9
								
Newborn	6 months	1 year 3 months	1 year 7 months	2 years 3 months	3 years 6 months	4 years	5 years 4 months	6 years

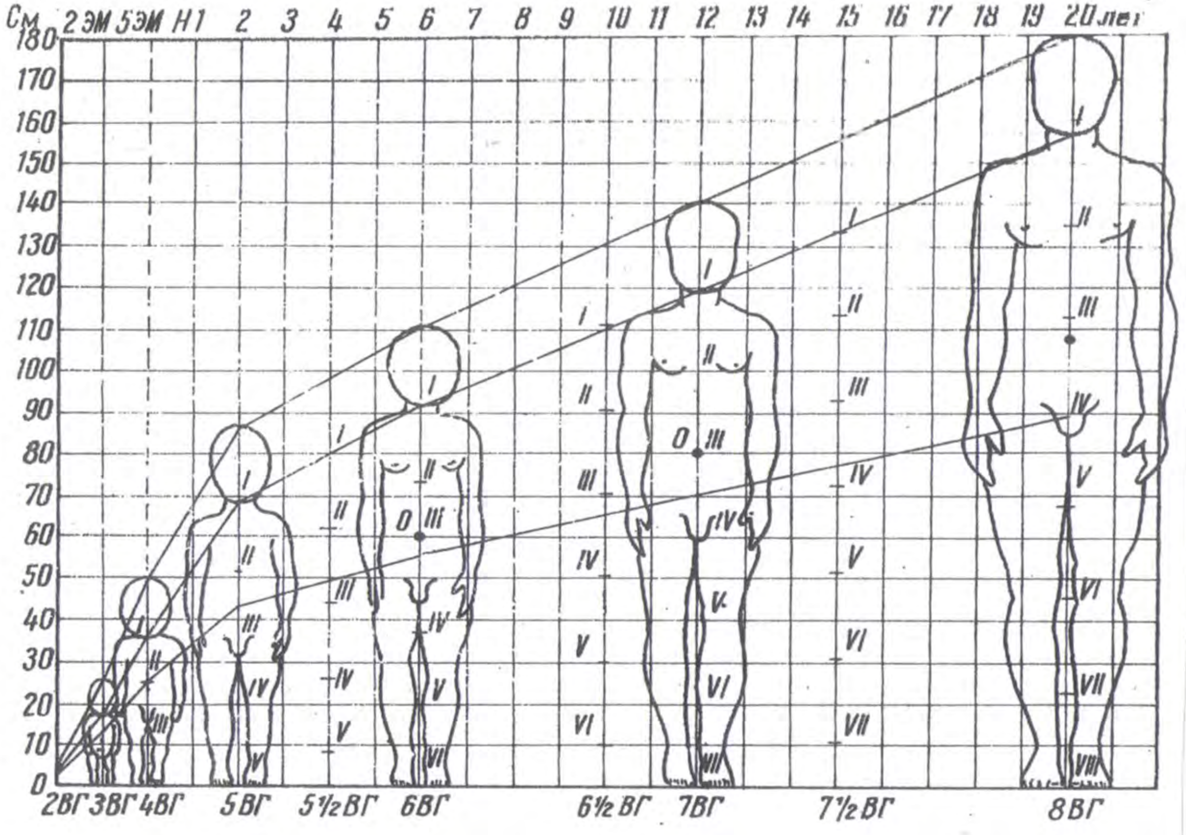
Table 1 Based on the data by G.Doman и E.Dukendjiev.

Locomotion type	Age [years]	Daily locomotion norm S [in meters]	
Crawling	1-2	68 ÷ 113	(S_1)
	3-6	75 ÷ 273	
Going on hands and knees	3-4	546 ÷ 720	(S_2)
	5-6	728 ÷ 910	
	from 7 years on	1456 ÷ 2184	
Bipedal walking	3-4	1435 ÷ 1893	(S_3)
	5-6	2184 ÷ 2730	
	from 7 years on	7207 ÷ 9000	

Table 4. Changes in proportion between body sections during growth process (Stratz)

Slow rate is observed in head growth compared to body and legs growth

EM – embryonal months; H – newborn; Roman numerals inside the drawing and below show by how many times the overall body length exceeds the head height (ВГ – head height)



The lane of the locomotor robot [5] should move at the minimum speed of V=0.1 [m/s]. The overall distance is determined by the choice and combination of various locomotion types $S = S_1+S_2+S_3$ [meters]. Locomotive sessions should coincide with the time of consumption of external biochemical energy, i.e., there should be five of them. Duration of an individual session (d) is calculated as follows:

S[m]:V=0.1[m/s]=D[c]:5sessions=d[s]x60x60=d[hours] (2)

If the deficit Δ can be compensated with the obtained parameters, a linear chart is drawn (Table 2).

Table 2 Obtained parameters.

Consumption of external biochemical energy		Consumption of external physical energy	
Feeing	Time	Session	Time
Breafast	30 min	No 1	d_1 sec
Second breakfast	30 min	No 2	d_2
Lunch	40 min	No 3	d_3
Afternoon luncheon	30 min	No 4	d_4
Supper	40 min	No 5	d_5
Total: $t_{\text{ф}}$ =170 min		Total: $D={}_1\Sigma^5 d_i$	

To the functional time $t_{\text{ф}}$ the time for communication, bathroom, etc., in the amount of at least $\Delta t_0=0.8\ t_{\text{ф}}$ should be added. After that the time balance for one day is calculated as follows:

$t_{\text{ф}} + \Delta t_0 + D \leq 12$ hours (3)

Change in the value of the components is possible providing that the overall resultant amount is constant depending on the condition of a child and the habilitation stage.

In case of the deficit exceeding 2 years (Δ=24 months) the computations are already made on the basis of minimum required time of sessions in one day. It is formally assumed that free time is equal to 12 hours and the number of physiologically required sessions is five. Then, the conditional duration of a session is calculated by the following formulas:

Δ[months] x 30 [days in one month] = Δ[days] (4)

Δ[days] x 12[hours] x 60 [min] x 60 [sec] = Δ[sec] (5)

Δ[sec] : 5 [sessions per day] = d[sec in one session] (6)

After that the chart is drawn that is patterned after Table 2 and the time balance for one day is obtained. In case of the late start of habilitation process and significant pathologies present the time balance may turn out negative. In that case it becomes necessary to increase the overall duration of habilitation process despite the fact that the obtained results are not going to achieve the intended effect.

For planning the process of habilitation and design of the robot it is necessary to determine the energy expenditure during locomotions on the robot. At a first step the net metabolic capacity ($Ё_{в}$) is determined, which corresponds to energy expenditure per time unit, where the amount of energy consumption during rest is subtracted from gross registered metabolic capacity by the formula suggested by Mahadeva A.O.

$$Ё_{в}\,[\text{kcal/min}]=0.047Q + 1.024 \tag{7}$$

where Q[kg] – the child’s weight.

The formula is valid at the lane speed of up to 1.34[m/s]. Obtained values serve the basis for planning external biochemical energy – the child’s feeding schedule. For calculation of the amount of external physical energy during walking on the lane the calculation table 22 designed by Zatsiorsky V.M. [5] is used. The pace speed of $V = 0.1 \div 1.8$ [m/s] requires net metabolic capacity $Ё_{в}$ from 1.13 to 9.97 [W/kg]. Accordingly, during the session that lasts d[sec] the amount of energy required is:

$$Ё_{в}[\text{W/kg}] \text{ x } d[\text{sec}]=E_{session}[\text{W/sec}]=0.27E_{session}[\text{kW/hour}] \tag{8}$$

III. CONCLUSIONS

For compensation of the overall deficit the external energy for the biotechnical system “child-robot” is required $E[\text{kW/hour}]= \Delta[\text{sec}].\ Ё_{в}\,[\text{W/sec}]\text{x } 0.27$.

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