

# GEORGIAN MEDICAL NEWS

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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии  
საქართველოს სამედიცინო სიახლენი

# GEORGIAN MEDICAL NEWS

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გამოიცემა თბილისის სახელმწიფო სამედიცინო უნივერსიტეტთან  
თანამშრომლობითა და მისი პატრონაჟით

This special issue of the journal is dedicated to Child & Adolescent Physiology and Related Topics  
Guest Editor – Professor Karaman Pagava

Данный номер журнала посвящается проблематике физиологии детей  
и подростков и пограничных вопросов  
Приглашенный редактор – профессор Караман Пагава

ჟურნალის ეს ნომერი ეძღვნება ბავშვთა და მოზარდთა ფიზიოლოგიასა  
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**ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ  
ТБИЛИСИ - НЬЮ-ЙОРК**

**GMN: Georgian Medical News** is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board and The International Academy of Sciences, Education, Industry and Arts (U.S.A.) since 1994. **GMN** carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.

**GMN** is indexed in MEDLINE, SCOPUS, VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

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Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

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3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

5. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრაფიების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შედეგების ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

6. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

7. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით.

8. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

9. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

10. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: შესავალი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.



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## CONCEPTS OF NEURODEVELOPMENT IN SPORTS ACTIVITY FOR ADOLESCENTS

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Countless millions of adolescents are taking part in sports activity (organized and unorganized) in all countries of the world. This important aspect of “growing up” has become an important part of the lives of our youth, either as participants or as observers [11]. Playing sports is now a method of building physical and socialization skills. Well-publicized adolescent sports prodigies are influencing parents and adolescents alike to become highly proficient at a specific sport with the dream of become famous as well as very wealthy in later adult life. Such dreams stimulate the issue neurodevelopmental maturation and readiness in sports activity based on the important concept embodied by the eternal question from parents and adolescent alike-when am I (he or she) ready to excel in sports, particularly in competitive sports?

This article highlights comments on this question for both teenager and parent, focusing on key underlying concepts as neurodevelopment and sports readiness [5,16].

### **Neurodevelopment in Sports Play**

*Neurodevelopment* involves growth and development of the person that involves not just bodily changes in puberty that includes sensory and perceptual growth but also changes in the central nervous system. As maturation in neurodevelopment occurs, the concept of *sports readiness* arises that is based on the fundamental physiologic concept that growth and development is a continuous normal process with a number of underlying independent factors that are involved: somatic development, neurological development, cognitive development, and normal social development of the adolescent [4]. Various developmental milestones in childhood and adolescence are arrived at sequentially but with a normal age range. This is noted in childhood by the observation that a child will not walk or run before specific levels of normal neurological maturity arise. Thus, training a child in

advanced sports will not be successful because the child is not yet neurodevelopmentally ready for such training. Intense training does not advance normal neurodevelopmental progress nor alter normal sequencing of sports readiness.

Clinicians can be of immense help to youth and parents by providing accurate information on growth and development. Physicians can help match youth with sports activities that match the youth’s stage of development. Children enter puberty at different ages with a wide age range - 6 years of age to 14 years, though most enter puberty between 10 and 12 years of age. The individual must have basic neurodevelopment to be able to master the fundamentals of a specific sport and as normal maturity progresses, more advanced sports skills can be learned based on the youth’s interest, desire to excel, genetic potential, and quality of training that is available. This applies to all youth, including those with physical and cognitive limitations or disabilities [5]. As the youth refines these milestones they can go from the “fun” of sports play to the potentially more serious “competitive” sports play that can bring improved social esteem, fame, and even wealth. The real purpose of the sports play is to translate it onto a lifetime of exercise, since very few can actually proceed to success at high levels of sports participation [6].

As noted, neurodevelopment involves growth and maturation of the central nervous system with additional attention to perceptual and sensory skills of the adolescent athlete [13]. Such growth and development involves individual variations in the rate of achievement and progression of milestones that are also sequential and deeply rooted in the athlete’s genetic background. There are various environmental factors that determine the success of sports play such as quality of available nutrition, quality of available sports equipment, and opportunities for sports play as well as proper coaching. Underlying neurological

maturation is a genetically based process while social and adoptive skills are under a wide range of factors including education, training, social expectations, and others.

Critical domains of neurodevelopment include those listed in Table 1. Dr. Arnold Gesell (1880-1961) was an American psychologist who wrote about “streams” of development (Table 2) [8]. In specific application to sports play, Fagard refers to skill as “proficiency with which an integrated activity is carried out” [9]. There are *quantitative* (i.e., number of milestones) versus *qualitative* milestones that refer to how well the athlete can perform tasks required for success in each sport activity.

Table 1. Critical Domains of Neurodevelopment

<ol style="list-style-type: none"> <li>1. Cognitive</li> <li>2. Physical or somatic</li> <li>3. Neurological</li> <li>4. Psychosocial or emotion</li> <li>5. Sensory-perceptual</li> </ol>
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Table 2. Gesell's “Streams” of Normal Childhood Development [8]

<ol style="list-style-type: none"> <li>1. Gross motor</li> <li>2. Fine motor</li> <li>3. Expressive language</li> <li>4. Receptive language</li> <li>5. Social and adaptive skills</li> <li>6. Visual-motor problem solving</li> </ol>
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*Physical growth* refers to specific changes in size of the adolescent’s height and body systems. *Maturation* is the rate of progress in finalizing a mature status including such areas as skeletal, somatic, and sexual domains. This is especially important to the adolescent because of such a wide variation in growth and development that are based on genetic patterns and on a chronological scale. Thus, skeletal growth can be advanced, average, or delayed with major impact on how the youth will perform in relation to his same-age peers. Changes in genital and sexual organs are measured by the classic Tanner Staging or Sexually Maturity Ratings (SMR) [3]. Continued growth allows maturation in posture, locomotion, fine motor as well as visual-motor skills in the upper extremities and also eye-hand coordination.

There are also changes in *cognitive development* (Table 3) that allow the athlete to go from performing simple tasks as a child to those involving more complex mental tasks as adolescents. The higher the youth advances in sports competition the higher levels of multiple domain integration that is required. This involves normal changes in visual-motor and auditory development that allow the athlete to keep track of numerous players on the field by both sight and hearing.

Table 3. Maturation Tasks of Cognitive Development

<ol style="list-style-type: none"> <li>1. Attention</li> <li>2. Judgment</li> <li>3. Mental processing speed or alertness</li> <li>4. Problem solving skills</li> <li>5. Thinking skills</li> </ol>
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**Sports Readiness** refers to the level of maturity of an individual allowing the adolescent athlete to acquire a desired level of proficiency to permit success in the selected sport. It is based on various factors including motor, physical, social, cognitive, and adaptive issues. This allows the athlete to coordinate complex functions and maneuvers that involved complicated movements of body parts (i.e., extremities), breathing, thinking, and balancing. It leads to coordinated processing ability, agility, flexibility, speed of thinking, strength, and endurance.

### Concepts of Sports Physiology in Adolescence

The child (pre-pubertal individual) usually has shorter extremities in relation to total body length than mature adolescents and adults. Children have a smaller muscle mass with limited strength and minimal response to strength exercises. Males and females can play sports together until about 10 or 11 years of age because they are usually of similar size and strength. As puberty begins usually between 10 and 12 years of age, males developed decreased body fat content, more lean body mass, and greater strength compared to same age females. Females increase their body fat percentage from pre-pubertal level of 19% to 23% as an adult. Once puberty develops it is wise to separate males from females because of the increasing strength of the male in contrast to the female. The risks of injuries to the female is simply too high except in select sports, such as archery, golf, tennis, and swimming. Principles of training adolescent males and females for increasing strength have been described [2,3].

### **Implications for Sports Participation**

The wide variation in pubertal onset and completion has considerable implications for sports play in adolescents. For example, a young adolescent with an early sexual maturity rating (SMR) or Tanner stage who appears to be awkward or clumsy, may simply need time to mature from an SMR viewpoint to be able to more effectively compete with peers and lose the label of being “clumsy or awkward.” It is important for the adolescent to have reached an appropriate level of neurodevelopmental and physiological maturation to effectively compete with same-age peers. Proper training and conditioning are always important but will not advance one who just needs more time for normal maturation based on his or her personal genetic code.

#### *Early Male Development*

The adolescent male with early pubertal development has an advanced bone age compared with chronological age, develops peak height velocity before his peers (before age 13), and tends to be taller with greater muscle mass, fat mass, and strength compared to his peers. He has greater strength (such as arm, grip, and explosive power for jumping or sprinting). Only one in four early male developers who are excelling in sports will continue to excel once his peers have caught up. This may result in the teenage male being called a “lazy” person when he can no longer compete at a high level, resulting in considerable depression in the adolescent and anger in the parent conditioned to expect to have a superstar athlete bring money and fame to the family.

#### *Early Female Development*

The adolescent female with early development may reach her peak height velocity before age 11, tends to be taller (than same age peers) with greater fat/fat free mass, more weight for height, relatively shorter legs, and broader hips. This usually is only a modest if any sports advantage with a social disadvantage. This is not an advantage for gymnastics, dancing, diving, or figure skating. It may also set up unrealistic predictions of stardom when other peers catch up to her, as noted with the early male developer.

#### *Late Male Development*

The late developing adolescent male has delayed bone age, may not reach peak height velocity before age 15 (later than his peers), is relatively shorter in stature, weaker, less coordinated, and experiences negative sports play (i.e., increased frustration, anxiety, and

disappointment). He is usually not able to meet performance expectations in sports and is often ignored by peers and the coaching staff.

#### *Late Female Development*

The late developing adolescent female may not reach her peak height velocity before age 13 years, tends to be taller than peers with lower weight for height, less fat mass, longer legs, and narrower hips. She often has a social advantage, performs better on upper extremity strength tests and has a sports advantage for gymnastics and figure skating.

### **Concepts of Sports Readiness**

#### *Pre-pubertal Development*

By 5 to 6 years of age the child can remember simple rules and play rudimentary games but does not comprehend the competitive nature of sports until 9 years of age or later. Those under age 6 play what is called “beehive soccer” in which they swarm around the soccer ball as a disorganized “gang” to kick the ball. It can be frustrating to uninformed coaches or parents, but it is simply normal behavior for age. One classic study noted that timing accuracy in tennis improved considerably between ages 7 and 10 [2,4,10]. Another study concluded that it was not until age 10 that children in South Africa has the appropriate neurodevelopment to master the basic (not advanced) skills needed to play rugby [11]. Another classic study concluded that pediatric athletes are not able to understand complex sports tasks until 12 years of age [12]. It is not possible to accurately predict which children will become super stars in a specific sport in the future and there are considerable mental health implications for children or youth pushed in the wrong direction given false and unsupported predictions of future greatness [13-15].

#### *Early Adolescence (Ages 11-14)*

Most normal maturing young adolescents are ready for entry level into competitive sports such as football, tennis, basketball, and baseball. Overall success is based on personal drive and genetics. However, these youth still require repeated teaching and demonstrations with sports instructions since they are usually in Piaget’s *Concrete Operational* thinking stage. They need a variety of sport experiences and should not yet “specialize” in only one sport unless this is clearly requested by the adolescent and not just the parent. This youth’s behavior is influenced by behavior of parents and peers. They have a hard time dealing with criticism from coaches and parents.



They have limited life experiences and react poorly to overt negative comments, such as: “You need to drop out!” or “You hit like a girl!” “You should be a superstar-what is wrong with you!” Bullying and teasing can be very detrimental at this stage of development.

#### *Middle Adolescence (Ages 14-17/18)*

Some youth at this stage find it difficult to adjust to their somatic growth spurt. The tall and thin male may be placed with shorter but more pubertally advanced players who are stronger, resulting in increased injuries to the tall male. The obese teenager may be competing against a similar weight but more muscular males and gets increased injuries because muscle is stronger than adipose tissue. This is especially true if the obese female is placed in a wrestling match with less obese males who are physiologically stronger. Middle adolescents must know if they have the needed skills and ability to understand the demands of their sports. They must learn to develop the appropriate emotional temperament to handle their chosen sport.

The more competitive the sport, the more pressure to meet a specific body type. Wrestlers find it difficult to maintain a desired weight; they may use pathogenic weight control measures or refuse to move to another weight class as they grow out of fear that they will lose. The females are now heavier and may use sports to keep their weight down; for example, growing dancers and gymnasts may use pathogenic measures to maintain an ultra-thin body that nature (puberty) is trying to change with normal gain in body fat levels. Defensive tackles in American football must bulk up (“i.e., gain massive weight) to meet a desired body type for a specific team position. Sports doping becomes very common in middle adolescents seeking every advantage possible to be successful in their chosen sport [8].

#### *Late Adolescence (Ages 18 to Adulthood)*

The late adolescent usually has the key skills to meet the demands of their sport from multiple levels: social, emotional, cognitively, visual-motor, and perceptual. Very few have the elite skills and motivation demanded for competition at the professional and Olympic level. It is important for clinicians to teach them to participate in sports for the fun of it to allow a lifetime habit of exercise, fitness, and recreation. Though many have dreams of glory, few are given the genetic potential to reach such high goals.

The term neurodevelopment refers to the synthesis of various functions of the adolescent athlete as reflected

in this article. Adolescent athletes must master various fundamental skills for each desired sports for effective sports play. Clinicians can guide the pediatric athlete from childhood to late adolescence to follow their acquisition of normal milestones. Youth can be delayed or precocious in their development with considerable impact on sports play. Clinicians can help youth of all neurodevelopmental and pubertal maturations participate in sports successfully and minimize the detrimental potential of sport participation. The actual purpose of youth sports play is to encourage a lifetime of exercise and fitness for a more enjoyable and productive adulthood [5,8,14].

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## SUMMARY

### CONCEPTS OF NEURODEVELOPMENT IN SPORTS ACTIVITY FOR ADOLESCENTS

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This article highlights comments on this question for both teenager and parent, focusing on key underlying concepts as neurodevelopment and sports readiness. Issues regarding neurodevelopment in adolescent sports are considered in this article. Understanding the neurodevelopment of the *Adolescent Athlete* and how this development impacts sports participation is critical for clinicians to provide parents, coaches, and sports organizers with valuable information about how to select activities for their children that will have a positive impact on their overall growth and development as well as optimize their benefit from sports play. Stories of child prodigies who began to learn a specific sport before age three stimulate parents to

question whether or not they also should be enrolling their very young children in such aggressive training programs. Physicians and health care sports professionals should provide information to other professionals and parents about issues related to successful sports participation of the pediatric athlete, both as a child and as an adolescent.

**Key words:** neurodevelopment, sports activity, adolescents.

## РЕЗЮМЕ

### РАЗВИТИЕ НЕРВНОЙ СИСТЕМЫ У ПОДРОСТКОВ, ЗАНИМАЮЩИХСЯ СПОРТОМ

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В данной статье рассматриваются вопросы развития нервной системы подростков, ориентированных на спорт высших достижений, даются разъяснения для родителей и подростков. Особое внимание обращается на основополагающие концепции – нейроразвитие и готовность к спорту. Как известно, спорт - это одна из разновидностей деятельности, основной формой которой является спортивное соревнование. Кроме того, спорт является разновидностью профессиональной деятельности и может быть охарактеризован теми же психологическими категориями, как труд, учение и игра. Успехи в спорте у детей, которых начали целенаправленно тренировать в возрасте до трех лет, ставят родителей перед необходимостью решать, не стоит ли начинать агрессивные тренировки уже в этом возрасте? Врачи и специалисты спортивной медицины должны представлять родителям и другим профессионалам всеобъемлющую информацию о спортивной активности детей и подростков. Клиницисты, должны представлять информацию родителям, тренерам и организаторам спорта касательно подбора тех видов спорта, которые будут иметь наилучшее влияние на полноценное развитие подростка и в котором подросток может достигнуть наибольшего успеха.

რეზიუმე

ნერვული სისტემის განვითარების კონცეფცია სპორტსმენ მოზარდებში

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სტატიაში განხილულია ნერვული სისტემის განვითარების საკითხები სპორტით დაკავებულ მოზარდებში. ფრიად მნიშვნელოვანია, რომ კლინიცისტებმა დროულად მიაწოდონ

მშობლებს, მწვრთნელებსა და სპორტის ორგანიზატორებს ინფორმაცია იმის თაობაზე, თუ რა სახის სპორტული აქტივობა იქნება სასარგებლო ბავშვებისთვის, მათი ზრდა-განვითარებისა და სპორტული მიღწევებისთვის. ცნობები ადრეულ ასაკიდანვე ბავშვების დიდ სპორტში ჩართვის წარმატებულობის შესახებ განაპირობებს მშობლების მოთხოვნას სამ წლამდე ასაკის ბავშვები ჩართულნი იყვნენ სპეციალურ სპორტულ აქტივობაში და ღებულობდნენ აგრესიულ სპორტულ დატვირთვას. ექიმები და სამედიცინო სპორტის მედიკოსი პროფესიონალები უნდა აწვდიდნენ ადეკვატურ ინფორმაციას მშობლებსა და სხვა პროფესიონალებს სპორტული აქტივობის ოპტიმიზაციის მისაღწევად ბავშვებსა და მოზარდებში.

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## ASSESSMENT OF ANTHROPOLOGICAL, PHYSICAL AND FUNCTIONAL INDICES IN SPORTSMEN (BASKETBALL PLAYERS) AGAINST THE BACKGROUND OF HIGH PHYSICAL LOADING

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Physical development of the organism is defined as the complex process of changes in morpho-functional peculiarities. It obeys to biological laws and reflects the general laws of growth and development.

The intensification of process of training [1,6,4] and systematic overloading of the organism causes the reduction of structural, physiological and other reserves. The intensive physical loading presents to the organism, especially to the action of its cardio-vascular system increased requirements. As a result, among the sportsmen the deficit condition is observed which may be accompanied by the depletion of functional reserves, negative effects and health disorder [2,8,10,13,14]. The basic characteristic of human health appears to be the condition of cardio-vascular system. The studying of functional condition of cardio-vascular system in

sportsmen in the conditions of long-term adaptation to physical loading is one of the actual problems of sport cardiology and physiology. Thus, the most significant problem of sport medicine is the acute and chronic overloading and its prophylaxis. From this point of view, it is necessary to reveal informative characteristics for the purpose of optimization of training process and the estimation of functional condition of sportsmen, its prognostication and management, as well as in order to avoid negative effects of adaptation to intensive physical loading [5,7,9,12].

The goal of the investigation was the estimation of functional condition of anthropometrical, physical and cardiovascular system of sportsmen-basketball players against the background of high physical loading.

Table 1. Changes in anthropometrical, physical and functional indices of basketball players before and after physical loading

Indicators	Before physical load			After physical load				
	Highest	Lowest	Mean	Highest	Lowest	Mean	t	p
Body mass	43,00	100,00	62,96±2,48	45,00	99,00	64,23±2,38	2,98	0,0053
Sitting height	94,00	136,00	123,29±1,44	96,00	140,00	124,97±1,49	4,58	0,0001
Standing height	152,00	190,00	168,46±1,52	154,00	191,00	169,91±1,56	4,12	0,0002
Diameter of shoulder	21,00	36,00	26,97±0,64	22,00	36,00	27,86±0,59	3,23	0,0028
Breast sagittal size	35,00	85,00	44,60±1,41	32,00	85,00	44,74±1,41	0,54	0,5949
Breast frontal size	36,00	87,00	45,96±1,41	36,00	87,00	46,69±1,39	2,25	0,0310
Diameter of right palm	15,00	19,00	17,37±0,19	15,00	20,00	17,43±0,20	1,00	0,3244
Diameter of pelvis	70,00	114,00	87,37±1,63	72,00	110,00	86,31±1,53	1,00	0,3244
Circumference of shoulder (during muscle strain)	23,00	89,00	31,91±1,83	23,00	89,00	31,97±1,83	3,24	0,0027
Circumference of forearm	20,00	31,00	25,69±0,44	20,00	31,00	25,66±0,43	2,07	0,0460
Circumference of shoulder	22,00	36,00	27,77±0,51	22,00	36,00	27,74±0,51	1,00	0,3244
Circumference of shin	27,00	43,00	33,94±0,66	27,00	43,00	33,91±0,67	1,00	0,3244
Circumference of weist	64,00	100,00	76,40±1,31	64,00	100,00	76,80±1,34	1,00	0,3244
T-1	90,00	130,00	114,57±1,40	90,00	130,00	113,86±1,45	1,00	0,3244
T-2	60,00	80,00	66,29±0,92	60,00	80,00	66,86±0,92	0,93	0,3592
R- after load	20,00	29,00	25,49±0,41	20,00	29,00	25,80±0,39	1,15	0,2572
R- after load -30 min	25,00	36,00	30,23±0,30	25,00	38,00	30,97±0,44	1,28	0,2105
R- after load -1 min	28,00	38,00	33,29±0,36	28,00	40,00	33,60±0,40	3,06	0,0306
R- after load -2 min	31,00	40,00	36,00±0,33	31,00	42,00	36,40±0,42	3,06	0,0044
P-before load	58,00	88,00	75,57±1,15	58,00	90,00	76,20±1,17	1,72	0,0938
P- before load -30sec	90,00	122,00	105,00±1,48	90,00	128,00	105,60±2,25	1,56	0,0308
P- before load -1 min	94,00	130,00	114,31±1,34	94,00	132,00	114,54±1,36	2,09	0,0437
P- before load -2 min	100,0	136,00	119,34±1,28	100,00	134,00	119,20±1,2	0,44	0,6662
R- after load -1 min	86,00	110,00	95,77±1,05	88,00	110,00	95,89±1,03	1,00	0,3244
P-blood pressure	30,00	65,00	48,43±1,40	30,00	65,00	48,29±1,37	1,00	0,3244
Mean blood pressure	75,00	105,00	90,50±0,97	75,00	105,00	90,43±0,96	1,00	0,3244
IKettle index	16,69	30,61	21,94±0,55	17,72	29,94	22,06±0,55	0,72	0,4774
Minuvre index of proportionality	23,44	93,62	37,35±2,30	21,88	90,63	36,65±2,26	1,41	0,1676
Breast development coefficient	-6,00	27,00	7,97±1,24	-6,50	26,00	7,94±1,20	0,10	0,9219
Pinie Index	-35,0	36,00	13,30±2,97	-33,00	30,00	12,77±2,89	0,84	0,4076
Ruffie Index	4,20	11,60	7,63±0,25	4,2	11,6	7,71±0,27	2,30	0,0277
Amec	1980,	5720,0	3683,00±138,6	1980	5850	3685,972±1	1,25	0,2214
Resistance coefficient	12,31	23,33	16,01±0,48	12,31	23,33	16,16±0,46	1,08	0,2858
Lilianstrand coefficient	35,29	70,27	53,47±1,43	35,29	70,27	53,30±1,35	0,04	0,9683
Cander Index	2320,	6183,7	4064,61±144	2320	6324,32	4074,39±138,	1,27	0,2127
Shtange test	34,00	68,00	53,69±1,68	34,00	68,00	54,03±1,68	1,67	0,1032
Gench test	18,00	39,00	26,57±0,83	18,00	40,00	26,97±0,87	1,87	0,0700

Table 2. The amplitude parameters of cardiac cycle in sportsmen-basketball players before and after physical loading

		Without physical load				Under physical load				p
		Mini- mum	Maxi- mum	M	m	Minimum	Maximum	M	m	
R	I	3	6	4,43	0,14	3	17	6,43	0,71	0,2854
	II	6	20	13,43	0,63	6	17	12,14	0,59	0,2872
	III	4	20	11,14	0,74	5	17	9,71	0,67	0,2716
	AVR	-1	1	0,71	0,11	-1	2	1,14	0,15	0,2567
	AVL	1	5	2,29	0,18	1	15	6,00	0,82	0,2598
	AVF	5	20	11,71	0,68	4	15	9,14	0,57	0,3202
	V1	1	8	4,29	0,40	1	16	6,71	0,98	0,2153
	V2	5	18	8,71	0,63	4	17	8,43	0,62	0,4108
	V3	7	21	10,14	0,71	7	20	10,14	0,65	0,5232
	V4	8	23	15,57	0,89	7	25	16,57	0,91	0,4394
	V5	10	22	18,86	0,60	18	24	20,57	0,28	0,4926
	V6	10	57	21,43	2,38	15	86	41,57	3,66	0,5656
S	I	1	2	1,14	0,05	1	2	1,14	0,05	1
	II	1	2	1,71	0,07	1	2	1,43	0,08	0,0002
	III	1	2	1,14	0,05	1	13	2,86	0,65	0,0131
	AVR	6	11	8,29	0,26	2	13	8,48	0,57	0,6802
	AVL	1	8	3,86	0,37	1	8	2,86	0,42	0,0001
	AVF	1	2	1,57	0,08	-1	8	2,43	0,42	0,036
	V1	2	20	10,57	0,85	2	18	10,57	0,64	1
	V2	2	17	11,29	0,74	9	20	14,48	0,65	0
	V3	2	20	10,86	0,82	6	15	9,29	0,45	0,0064
	V4	2	15	9,00	0,69	1	18	8,43	0,85	0,5318
	V5	4	12	7,14	0,38	2	12	5,14	0,46	0
	V6	2	9	4,71	0,39	3	12	5,13	0,54	0,0033
P heath	I	1	1	1,00	0,00	1	2	1,14	0,05	0,0125
	II	1	2	1,43	0,08	1	2	1,67	0,07	0,0312
	III	1	2	1,43	0,08	1	2	1,29	0,07	0,0125
	AVR	-2	1	-0,29	0,18	-2	1	-0,29	0,23	1
	AVL	1	2	1,14	0,05	1	1	1,00	0,00	0,0125
	AVF	1	2	1,29	0,07	1	2	1,29	0,07	1
	V1	-1	1	0,71	0,11	-1	1	0,71	0,11	.
	V2	-1	2	0,86	0,13	1	2	1,14	0,05	0,0441
	V3	1	2	1,14	0,05	1	2	1,14	0,05	1
	V4	1	2	1,14	0,05	1	2	1,43	0,08	0,0002
	V5	1	2	1,29	0,07	1	2	1,29	0,07	1
	V6	-1	2	1,00	0,14	1	2	1,17	0,06	0,0438
P width	I	0,1	0,12	0,11	0,00	0,1	0,12	0,11	0,00	0,0125
	II	0,1	0,12	0,11	0,00	0,1	0,14	0,12	0,00	0,0002
	III	0,1	0,14	0,12	0,00	0,1	0,14	0,11	0,00	0,1598
	AVR	-0,12	0,14	0,08	0,01	0,1	0,14	0,12	0,00	0,0055
	AVL	0,1	0,12	0,11	0,00	0,1	0,12	0,11	0,00	0,0125
	AVF	0,1	0,12	0,12	0,00	0,1	0,12	0,11	0,00	0
	V1	0,1	0,12	0,11	0,00	0,1	0,12	0,11	0,00	1
	V2	0,1	0,12	0,10	0,00	0,1	0,12	0,11	0,00	0
	V3	0,1	0,2	0,13	0,00	0,1	0,12	0,11	0,00	0,031
	V4	0,1	0,12	0,11	0,00	0,1	0,14	0,12	0,00	0,0002
	V5	0,1	0,12	0,11	0,00	0,1	0,12	0,11	0,00	0,5336
	V6	0,12	1	0,37	0,06	0,1	1	0,37	0,06	0,0125

T+	I	0,3	4	2,19	0,18	2	4	2,67	0,11	0,0152
	II	0,4	4	2,63	0,18	2	5	3,10	0,16	0,0075
	III	0,2	2	1,46	0,11	-3	22	3,43	1,22	0,1026
	AVR	-5	3	-2,14	0,36	-4	2	-1,48	0,31	0,0019
	AVL	1	2	1,57	0,08	-2	2	1,19	0,18	0,0657
	AVF	1	4	2,36	0,15	1	4	2,40	0,16	0,7361
	V1	-3	2	0,21	0,33	-2	4	0,14	0,40	0,7987
	V2	3	6	4,14	0,15	3	7	4,81	0,25	0,0019
	V3	3	7	5,14	0,19	2	9	5,29	0,38	0,6547
	V4	3	7	5,43	0,22	2	11	5,33	0,45	0,8143
	V5	3	8	5,43	0,25	2	10	4,71	0,41	0,0368
	V6	0,4	10	4,63	0,41	2	7	4,00	0,24	0,032
QT	II	0,3	0,36	0,33	0,00	0,28	0,32	0,31	0,00	0
QT1	II	0,15	0,22	0,20	0,00	0,15	0,2	0,19	0,00	0,0128
T	I	0,02	0,04	0,03	0,00	0,02	0,04	0,03	0,00	0,0441
	II	0,03	0,04	0,03	0,00	0,02	0,04	0,03	0,00	0,3232
	III	0,02	0,04	0,03	0,00	0,02	0,04	0,03	0,00	0,3608
	AVR	0,03	0,22	0,06	0,01	0,02	0,04	0,03	0,00	0,0061
	AVL	0,02	0,04	0,03	0,00	0,02	0,04	0,03	0,00	1
	AVF	0,03	0,04	0,04	0,00	0,02	0,04	0,03	0,00	0,0016
	V1	0,03	0,05	0,04	0,00	0,03	0,06	0,04	0,00	0,0441
	V2	0,03	0,06	0,05	0,00	0,04	0,06	0,05	0,00	0,3608
	V3	0	0,06	0,04	0,00	0,03	0,06	0,04	0,00	0,1436
	V4	0,03	0,08	0,05	0,00	0,02	0,06	0,04	0,00	0,0019
	V5	0,03	0,04	0,04	0,00	0,01	0,04	0,04	0,00	0,1226
	V6	0,03	0,04	0,04	0,00	0,02	0,04	0,04	0,00	0,0441
QRS	I	0,08	0,16	0,13	0,00	0,1	0,13	0,11	0,00	0,0001
	II	0,08	0,16	0,13	0,00	0,1	0,15	0,12	0,00	0,0611
	III	0,06	0,16	0,11	0,00	0,1	0,12	0,12	0,00	0,3635
	AVR	-0,1	0,16	0,10	0,01	-0,1	0,14	0,11	0,01	0,3734
	AVL	0,08	0,14	0,12	0,00	0,1	0,16	0,12	0,00	0,3869
	AVF	0,08	0,16	0,12	0,00	0,1	0,14	0,12	0,00	0,8394
	V1	0,1	0,16	0,12	0,00	0,1	0,14	0,12	0,00	0,5853
	V2	0,08	0,16	0,13	0,00	0,08	0,14	0,13	0,00	0,5336
	V3	0,1	0,16	0,13	0,00	0,1	0,14	0,12	0,00	0,0248
	V4	0,1	0,16	0,13	0,00	0,1	0,14	0,13	0,00	0,4003
	V5	0,08	0,14	0,12	0,00	0,12	0,14	0,13	0,00	0,0009
	V6	0,1	0,15	0,12	0,00	0,12	0,3	0,16	0,01	0,0018
ST	I	0,13	0,18	0,16	0,00	0,13	0,18	0,16	0,00	0,6751
	II	0,12	0,19	0,16	0,00	0,12	0,18	0,15	0,00	0,0441
	III	0,14	0,2	0,17	0,00	0,13	0,18	0,15	0,00	0
	AVR	-0,23	0,17	0,08	0,02	-0,23	0,17	0,13	0,01	0,0098
	AVL	0,14	0,18	0,16	0,00	0,12	0,18	0,15	0,00	0,0932
	AVF	0,14	0,18	0,16	0,00	0,12	0,17	0,15	0,00	0,0204
	V1	0,12	0,17	0,14	0,00	0,12	0,17	0,14	0,00	0,258
	V2	0,13	0,16	0,14	0,00	0,1	0,16	0,13	0,00	0,0014
	V3	0,13	0,2	0,15	0,00	0,1	0,17	0,14	0,00	0,1417
	V4	0,12	0,16	0,14	0,00	0,11	0,18	0,15	0,00	0,512
	V5	0,12	0,18	0,16	0,00	0,1	0,18	0,14	0,00	0,0084
	V6	0,12	0,18	0,16	0,00	-0,04	0,19	0,12	0,01	0,002

**Material and methods.** The results of the investigation of the indices of physical development and cardio-vascular system condition as well as the results of adaptation to the physical loading of 100 basketball players at the age from 12 till 18 years underlay the study. The criteria of inclusion: satisfactory social and economic conditions, satisfactory and good sports results. Randomized and open controllable research was carried out during 6 months. The following characteristics have been studied: how many days the sportsman is training in a week, how many hours the sportsman is training per day, his mood after training, over fatigue and overtension, frequency of heartbeat, time of breath holding, the general condition, the height in sitting and standing position; circumference of lumbus, chest, arm and limbs, the pulse, pulse, systolic and diastolic arterial pressure before and after physical loading. According to these factors the following sport indices are calculated: Index of Rufe (physical work capacity), the coefficient of endurance (Kvas formula), Shtange test (breath holding at sighing), Genchi test (breath holding at exhalation), average arterial pressure, systolic and cardiac output of blood circulation (the formula of Lilienstrad and Tsander), the coefficient of blood circulation effectiveness, Kettle index (the ratio of height and weight), Minuvre index (the ratio of body and feet length), Pinie index (power of body-build).

The estimation of reliability of quantitative indices was done by Student criterion (t), while qualitative indices were estimated by means of  $\chi^2$  criterion. The mathematical support was accomplished by the use of SPSS-11 program.

**Results and their discussion.** At the first stage of investigation the comparative analysis of anthropometrical, physical and functional indices of basketball players against the background of physical loading have been studied (table 1).

According to the indices of the weight, height, the diameter of arm and chest, the circumference arm and forearm there were not found any considerable changes. After the loading only the frequencies of breath and pulse, as well as pulse pressure increased; after the loading the reduction of heartbeat frequency and average pressure also took place. Besides, such functional data as respiratory indices (Shtange and Genchi tests), Rufe index, the coefficient of endurance, systolic and cardiac output of blood circulation

(the formula of Lilienstrad and Tsander) have been changed, the coefficient of blood circulation effectiveness has worsened.

The following stage of investigation the amplitude parameters of cardiac cycle were studied in sportsmen-basketball players before and after physical loading (table 2).

As it turned out, amplitude indices of R wave were not changed after physical loading; S - reliably decreases in II, AVL, V3, V5 derivations and reliably increases in AVF and V6 derivations; P - height reliably increases in I, II, V2, V4 and V6 derivations and reliably decreases in III and is negative in AVL derivations. P - the width reliably decreases in I, AVL, V3 and V6 derivations and reliably increases in AVR and V4 derivations; T+ reliably decreases in V5 and V6 derivations and reliably increases in I, II, AVR and V2 derivations; QT and QT1 reliably decrease. T - reliably decreases in AVR, AVF, V4 and V6 derivations and reliably increases in I and V1 derivations; QRS - reliably decreases in I and V3 derivations and increases in V5 and V6 derivations; ST - reliably decreases in II, AVF, V2, V5, V6 derivations and increases in AVR derivation.

### Conclusions

Statistically authentic increase of breath and pulse in frequency was observed in sportsmen-basketball players after physical loading. The study of amplitude parameters of cardiac cycle among sportsmen-basketball players before and after physical loading has revealed the ability of rather low adaptation of cardiovascular system to physical loading.

Thus, with the aim of prevention of pre-pathological and pathological state of sportsmen the well-timed diagnostics of dysadaptation symptoms and functional disorders is necessary, as well as to carry out preventive measures and the correction and individualization of sport training process.

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## SUMMARY

### ASSESSMENT OF ANTHROPOLOGICAL, PHYSICAL AND FUNCTIONAL INDICES IN SPORTSMEN (BASKETBALL PLAYERS) AGAINST THE BACKGROUND OF HIGH PHYSICAL LOADING

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The goal of the investigation was the estimation of functional condition of anthropometrical, physical and

cardiovascular system of sportsmen-basketball players against the background of high physical loading.

100 basketball players at the age from 12 till 18 years underlay the study. Randomized and open controllable research was carried out during 6 months. The following characteristics have been studied: how many days the sportsman is training in a week, how many hours the sportsman is training per day, his mood after training, over fatigue and overtension, frequency of heartbeat, time of breath holding, the general condition, the height in sitting and standing position; circumference of lumbus, chest, arm and limbs, the pulse, pulse, systolic and diastolic arterial pressure before and after physical loading. According to these factors the following sport indices are calculated: Index of Rufe (physical work capacity), the coefficient of endurance (Kvas formula), Shtange test (breath holding at sighing), Genchi test (breath holding at exhalation), average arterial pressure, systolic and cardiac output of blood circulation (the formula of Lilienstrad and Tsander), the coefficient of blood circulation effectiveness, Kettle index (the ratio of height and weight), Minuvre index (the ratio of body and feet length), Pinie index (power of body-build). Statistically authentic increase of breath and pulse in frequency was observed in sportsmen-basketball players after physical loading. The study of amplitude parameters of cardiac cycle among sportsmen-basketball players before and after physical loading has revealed the ability of rather low adaptation of cardiovascular system to physical loading.

**Key words:** Sportsmen adolescents, physical indices, cardio-vascular system.

## РЕЗЮМЕ

### АНТРОПОМЕТРИЧЕСКИЕ, ФИЗИЧЕСКИЕ И ФУНКЦИОНАЛЬНЫЕ ПОКАЗАТЕЛИ У СПОРТСМЕНОВ (БАКЕТБОЛИСТОВ) ПРИ ФИЗИЧЕСКОЙ НАГРУЗКЕ

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Целью исследования явилось определение антропометрических и физических показателей,

а также функционального состояния сердечно-сосудистой системы у спортсменов при высокой физической нагрузке.

Обследовались 100 баскетболистов в возрасте от 12 до 18 лет. На фоне высокой физической нагрузки определялись показатели физического развития и функционального состояния сердечно-сосудистой системы (индекс Руффе, формула Кваса, тест Штанге, тест Генчи, формула Либлиенштрада и Цандера, индекс Кетле, индекс Минувра, индекс Пинье).

Выявлено статистически достоверное повышение частоты пульса и дыхания. Изучение амплитудных параметров сердечного цикла у баскетболистов, до и после физической нагрузки, показало низкую адаптацию сердечно-сосудистой системы на физическую нагрузку.

Установлено, что для превенции патологических процессов у спортсменов необходимо проведение лечебно-профилактических мероприятий, выявление ранних симптомов дисадаптации и индивидуализация тренировочных нагрузок.

### რეზიუმე

სპორტსმენთა (კალათბურთელები) ანთროპომეტრული, ფიზიკური და ფუნქციური მახასიათებლები ფიზიკური დატვირთვის ფონზე

გ. ჩახუნაშვილი, ნ. ჯობავა, მ. ლუჭაშვილი, კ. ჩახუნაშვილი,  
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შრომის მიზანი იყო სპორტსმენ კალათბურთელები ანთროპომეტრული, ფიზიკური და გულ-სისხლძარღვთა სისტემის ფუნქციური მდგომარეობის შეფასება მაღალი ფიზიკური დატვირთვის ფონზე.

სამუშაოს საფუძვლად დაედო 12-დან 18 წლამდე ასაკის 100 კალათბურთელის ფიზიკური განვითარებისა და გულ-სისხლძარღვთა სისტემის (გსს) მდგომარეობის მაჩვენებლები და დატვირთვაზე ადაპტაციის გამოკვლევის შედეგები.

ჩატარდა რანდომიზებული ღია კონტროლირებადი კვლევა 6 თვის განმავლობაში.

დასკვნები: სპორტსმენ კალათბურთელებში ფიზიკური დატვირთვის შედეგად აღინიშნა

სუნთქვისა და პულსის სიხშირის სტატისტიკურად სარწმუნო მატება.

სპორტსმენ კალათბურთელებში გულის ციკლის ამპლიტუდური პარამეტრების შესწავლამ დატვირთვამდე და ფიზიკური დატვირთვის შემდეგ გამოავლინა ფიზიკური დატვირთვაზე გსს-ის შედარებით დაბალი ადაპტაციის უნარი.

ამგვარად, სპორტსმენებში პრეპათოლოგიური და პათოლოგიური მდგომარეობის პრევენციის მიზნით აუცილებელია დისადაპტაციის სიმპტომებისა და ფუნქციური დარღვევების დროული დიაგნოსტიკა, პროფილაქტიკური ღონისძიებების ჩატარება, და სპორტული წვრთნის პროცესის კორექცია და ინდივიდუალიზაცია.

## BODY COMPOSITION AND PHYSICAL CAPACITY OF ELITE ADOLESCENT FEMALE TENNIS PLAYERS

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Tennis is among the most popular sports throughout the world. The number of recreational and professional players is continually increasing. It has been roughly estimated that more than 35 million people are actively engaged in USA and more than 5 millions do it frequently. So is in Europe where millions play regularly, and a number of young players increases systematically. In Poland, more than 2500 children take part in the official tournaments each year. Some of them has become the elite players enrolled in the official rankings, including the national singles ranking and International Tennis Federation's Junior Circuit ranking (ITFJC). Tennis provides a tremendously effective fitness activity with a versatile motion patterns, diverse intensities, tempos, strokes and prolonged physical performance given the potential variability in games per match, sets per match, and matches per tournament [19]. Regular tennis players experience a variety of health-related benefits, from improved cardiovascular, musculoskeletal, and metabolic functions, to ameliorated agility, coordination, and even management of stress and anxiety.

There is a substantial data on physiological demands in regular adult tennis players [8]. Recently, there has been a growing interest in young elite tennis representatives and factors influencing their physical performance, but only a few data has been already published. The still open issue is the relationship between body growth and physical capacity or specific technical skills within young players, even though it would appear particularly essential for effective training, as the puberty is a period of most rapid and significant changes of an organism. Elite and sometimes recreational tennis players are involved in a sport that applies high repetitive loads, associated with tension overload challenge. International adolescent high level competition has the potential to be an extremely stressful and injurious experience [3,21]. Excessive workload may disturb an individual development [5], including temporal changes in the DNA strands [28].

The appropriate physical and psychological preparation is practically verified during tennis tournaments and consequently, in the ranking classifications. Regular monitoring of the somatic development during adolescence combined with assessment of endurance capacity can certainly improve future performance and prospective for a professional career.

The present study was undertaken to evaluate the relationships among the major antropological parameters, physical capacity, and the ranking position as an index of the temporal success.

**Material and methods.** *Subjects* Seventeen elite level, junior female tennis players (age range 15-17 years; height  $167.9 \pm 5.4$  cm; body mass  $58.1 \pm 7.7$  kg) were recruited into the study. Each participant regularly trained and played tennis, and was included in the national singles ranking (positions between 1<sup>st</sup> and 80<sup>th</sup>) and in the International Tennis Federation's Junior Circuit ranking (ITFJC; positions 21 to 990). The average period of regular tennis playing was  $8.6 \pm 1.1$  year, and the weekly training sessions during the six months before testing were 19-20 hr per week. The volunteers were divided into three age-matched groups (15 year-old, G15, n = 6; 16 year-old, G16, n = 4, and 17 year-old, G17 n = 7). The participants and their parents were informed in detail about the study and possible risks. Written informed consent was given by each subject's parents. The study was approved by the Human Ethics Committee at Academy of Physical Education and Sport.

*Anthropometric measurements* Body mass (BM) and body composition were estimated using a bioelectrical impedance floor scale (TBF-300 Body Fat Monitor/Scale Analyzer, Tanita, Japan) calibrated in accordance with manufacturer guidelines prior to each test session. One hour following a light breakfast, participants voided their bladder and bowels and underwent duplicate measures while in the standing position

recommended by the manufacturer guidelines. The average of the two values was used for final analysis. Assessment of the participant's biological maturity level was completed using the biological age determination method utilizing standard, gender-specific, height and weight percentile charts as adjusted for children from Warsaw and accepted as universal for Poland.

**Aerobic capacity measurement.** Maximal oxygen uptake ( $VO_{2max}$ ) was used as an index of aerobic capacity. To estimate  $VO_{2max}$  participants performed the 12-min Cooper's test [11]. Volunteers were allowed a 3-min warm up. Then a 12-min run was performed individually on an outdoor tartan running track in a way to cover a possibly long distance within the given time limit. After a call of "ready" the exercise began from a standing start. When the run time elapsed the final position of each participant was marked on the running track. The run distance, approximated to the nearest 5 m, was recorded. The test was conducted only once. Maximal oxygen uptake was calculated using the formula  $VO_{2max}=0.0268(\text{distance, meters})-11.3$ .

**Anaerobic power measurement.** Participants performed the Wingate anaerobic power test (WAnT) on a mechanically-braked cycle ergometer (884E Sprint Bike, Monark, Sweden) according to the modified Bar-Or procedure [32]. The testing session started with a standardized 5-min warm up cycling at  $1.0 \text{ W} \cdot \text{kg}_{BM}^{-1}$  including two all-out sprints lasting 3-5s each, against the resistance used for the test. Following a 5-min rest, the WAnT began from a stationary seated position with a right foot placed onto the ergometer pedal fixed at approximately 45 degrees as previously described [20]. While got ready to start

up, the participants were instructed to maximally accelerate their pedaling rate. Then they were verbally encouraged to maintain this pedaling cadence in a seated position as long as possible throughout the 15s test. Usually, at the very beginning of the test and also within the last seconds of the challenge most participants were unable to maintain seated position. Pedaling at standing position helped overcome the resistance and to achieve the maximal pedaling rate. A flywheel resistance was  $0.075 \text{ kg} \cdot \text{kg}_{BM}^{-1}$  (corresponding to 7.5% of each individual's BM) and was applied at the onset of the WAnT. The basic anaerobic parameters were determined from the 15s Wingate sprint data for each participant using the Multi Cyclo Ergometer System (MCE v 5.1 Software, Sport Institute, Warsaw, Poland).

Blood samples were collected from an antecubital vein before and after the WAnT procedure. The blood was deproteinized by the addition of ice cold 0.4 M perchloric acid. After being thoroughly mixed, the samples were centrifuged at 12,000g for 10 min. Blood lactate was determined using a standard Randox (UK) kit based on the lactate oxidase method (LC2389); assays were performed on a Cecil CE9200 spectrophotometer.

Statistical analyses were performed using Statistica 9.0 for Windows. Data are expressed as mean values  $\pm$  SD. The difference between the mean values among groups was evaluated with analysis of variance (ANOVA), with use of F- test for post hoc comparisons. Pearson linear regression was calculated to evaluate correlations between the tested variables, including analysis of trend related to age. Statistical significance was set at  $p < 0.05$ .

Table 1. Characteristics of the female tennis players

Variable	G15 (n=6)	G16 (n=4)	G17 (n=7)	All (n=17)
Height (cm)	164.0 $\pm$ 6.3	169.2 $\pm$ 2.4	170.4 $\pm$ 4.4	167.9 $\pm$ 5.4
Biological age of height (percentile)	54.6 $\pm$ 31.3	73.2 $\pm$ 6.3	77.2 $\pm$ 23.5	68.3 $\pm$ 25.1
Weight (kg)	52.8 $\pm$ 6.8	59.2 $\pm$ 9.6	62.0 $\pm$ 5.3	58.0 $\pm$ 7.7
Biological age of weight (percentile)	55.0 $\pm$ 18.9	71.0 $\pm$ 11.0	72.0 $\pm$ 20.0	65.8 $\pm$ 18.8
FFM (kg)	42.7 $\pm$ 3.8	44.4 $\pm$ 3.5	47.6 $\pm$ 3.6	45.1 $\pm$ 4.1
Fat %	18.3 $\pm$ 2.8	23.8 $\pm$ 8.4	22.7 $\pm$ 3.2	21.0 $\pm$ 5.0
Fat (kg)	10.0 $\pm$ 2.9	14.6 $\pm$ 6.7	14.1 $\pm$ 2.9	12.8 $\pm$ 4.3
BMI (kg/m <sup>2</sup> )	9.4 $\pm$ 1.8	20.6 $\pm$ 3.0	21.3 $\pm$ 1.8	20.4 $\pm$ 2.1

values are means  $\pm$  SD, G15, G16, G17 – each category of age; Fat = fat mass, FFM = free fat mass, BMI = body mass index



**Results and their discussion.** Detailed anthropometric characteristics is presented in Table 1. There were significant age-related trends in increase in height, body weight, FFT (free fat mass) as well as Fat% (Table 1). The difference between the age group G15 and G17 was: height: +6,4 cm (+3,9%), body weight +17,42%, FFM +11,48%, and Fat% 24,04%. Moreover, at mean age of 15 the physical stature of the group was close to age-matched standard, but 17-agers tended to shift to the fourth quartile.

It is generally accepted that in the North and Central European female population, including Poland, height stabilizes at an average age of 15 years, although a relevant individual variability is observed [15]. Some girls continue to grow up regressively and reach maximal adult height at age of 17-18, but the maximal height is usually only 2-3 cm higher than at age of 15. Intensive athletic training and competition is related to increased metabolic demands, which in turn may affect temporary control of growth. The rate of individual growth is tightly linked to timing of sexual maturation. In Poland, girls usually begin menstruating at age 12-13. Just before the puberty, the height boosts markedly with the peak rate of body growth to occur at approximately 12.5 years [15]. Soon, one to two years later, body growth is compromised. In this context, the growth spurt observed in the 15- to 17-year-old female tennis players was an unexpected finding. The literature concerning an influence of strenuous regular exercise on physical development and maturation is inconsistent: deleterious or salutary effect as well as lack of any evident effect have been reported [16]. Eisenmann and Malina [6] stated that intensive endurance training does not disrupt normal growth in children or adolescents nor influences maximal height attained, although the most recent surveys have indicated a boundary between tolerable and excessive levels of exertion especially when coupled with caloric limitation [7,18]. Low physical activity and high-fat diet has been documented to promote earlier pubescence and earlier termination of growth [13]. On the other hand, a delay in somatic growth and sexual maturation was well documented among certain groups of elite female athletes, most notably gymnasts, dancers, and long-distance runners [17]. A remarkable report was published by Claessens et al [4] who observed delayed maturation and growth. the median age at menarche was 15.6±2.1 yr among a group of gymnasts, compared to 13.2±1.2 yr in the control population. Erlandson et al. [7] argued that regular training did not affect final adult stature. The

point is that regular strenuous training is likely inflict the timing of individual growth. Young gymnasts were reported significantly shorter than tennis players and swimmers at all chronological ages during adolescence [7]. Most recent longitudinal study revealed [18] that extensive regular training especially combined with inadequate nutrition caused a growth delay in elite young athletes, but this delay did not appear to affect permanent adult height. Here, comparison of the anthropological indexes of biological age: percentiles of body weight (+30,91% G17 vs. G15) and height (+41,39% G17 vs. G15) indicates high dynamics of somatic growth in the observed junior elite tennis players. Biological age expressed in percentile did not correspond to the tennis ranking and physical capacity in the whole group. Adolescent teenagers often exhibit quite large deviations from the percentile lines depicted at early childhood. Most of such deviations depend on tempo of the pubertal growth spurt and is to occur much earlier than we found in this study. The possible explanation is that at younger age the overall training load was high enough to suppress a standard individual developmental pattern. Until reaching some age (in this study it seems to be at approximately 15 years) or appropriate body weight, the rate of growth was likely reduced. Then, on average at age 15-16, the total exercise load was no longer strenuous enough to be suppressive. Catch-up growth, resembling our data, was reported in young gymnasts when their training was temporarily reduced or stopped [27].

Interesting finding is that as much as 76,5% participants were born in the first half of year. As shown in Tab.1 the partakers had a long training experience (from 7,4±0,8 yr in G15 group to 10.2±1.5 y in G17 group). The majority started regular training at age 7 to 8 within groups born at the same year. The 15-17 years old partakers of this study, who became elite junior sportsmen with a prospective for professional career, had been initially a small proportion of children attracted to tennis. From almost the very beginning the training was competitive and selective. At a given year of birth, children born in the beginning of the year were bigger, stronger, and had better coordination than those from late months. Since tennis is extensively demanding in terms of applied patterns of motion and physical capacity, the small age advantage gave a benefit and provided a better score at a game. The relatively younger ones could feel frustrated and gave up. The similar personal observations were also noted in other sport disciplines. The disparity in proportion between those born in the first and the second

part of the year indirectly support the point that regular tennis training at the competitive level is at high risk for overuse and implicate impaired somatic growth and risk of injury .

The average BMI was  $20.4 \pm 2.1 \text{ kg (m}^2\text{)}^{-1}$  (Table 1). The observed trend for an increase in BMI with age was statistically insignificant. The percentage level of fat mass (Fat%) amounted to  $21.0 \pm 5.0\%$  among participants, while the average of the lean body mass (FFM) ranged between 40.9 kg and 49.1 kg ( $45.1 \pm 4.1 \text{ kg}$ ). Both FFM and Fat% were significantly higher in group of 17-year old partakers compared to those of 15 yr (Table 1; FFM  $42.7 \pm 3.8 \text{ kg}$  vs.  $47.6 \pm 3.6 \text{ kg}$ ). High energy expenditure may not only modify the linear growth rate but also the relative proportions of fat-free and fat mass [25]. In this study, neither significant differences in the proportion between FFM and Fat%, nor an age-related trend was observed ( $2.33 \pm 0.32$ ;  $1.87 \pm 0.39$ ,  $2.10 \pm 0.28$  – in the groups of age 15, 16, and 17, respectively). It has been recently reviewed that regular tennis playing appear to have positive health benefits, including lower body fat percentages, favorable lipid profiles, enhanced aerobic fitness, and improved risk profile for cardiovascular morbidity [23]. Consistently, obtained value of BMI, FFM, Fat% were closer to the recommended standards. There was no significant correlation between the body composition and ranking position ( $r = 0.1985$ , body weight vs. ITFJC;  $r = 0.0929$ , height vs. ITFJC;  $r = 0.2093$ , BMI vs. ITFJC;  $r = 0.1882$  FFM vs. ITFJC;  $r = 0.1448$ ,

Fat% vs. ITFJC). The obtained data do not meet the previous report where significant differences in height and humeral and femoral breadths between the top twelve and the lower ranked girls were found [26]. In fact, the sample studied was somehow different from our group: the tennis players were younger, up to 16 years old, and much more diversified – young tennis players representing 28 national teams from all over the world were enrolled.

Estimation of maximal oxygen uptake ( $\text{VO}_2\text{max}$ ) is considered the optimal method to assess aerobic fitness. Direct measurement of oxygen uptake requires oxygen spirometry while performing the maximal effort and difficult to employ during a regular training or a game. Such effort needs high motivation and predisposes to unwanted adverse effects related to overload and extreme stimulation of the adrenergic system. One of the most reliable and generally approved method of  $\text{VO}_2\text{max}$  estimation, is an indirect test based on assessment of maximal distance covered during 12-min run of a track (Cooper test). It is generally accepted that the distance assessed in the Cooper test strictly correlates to  $\text{VO}_2\text{max}$  obtained in the direct laboratory measurements with use of the oxygen spirometry. In case of regular tennis players the correlation is even higher than in average population since they are well adapted and accustomed to running. The average distance covered in the Cooper test was  $2635 \pm 168 \text{ m}$ , what, after calculation, gave the oxygen uptake,  $\text{VO}_2\text{max}$ ,  $59.3 \pm 4.5 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  (Table 2).

Table 2. Aerobic capacity and training and ranking position

Variable	G15 (n=6)	G16 (n=4)	G17 (n=7)	All (n=17)
$\text{VO}_2\text{max (mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}\text{)}$	$59.1 \pm 3.1$	$61.7 \pm 4.1$	$58.0 \pm 5.6$	$59.3 \pm 4.5$
Amount of playing tennis (yr)	$7.4 \pm 0.8$	$8.3 \pm 1.0$	$10.2 \pm 1.5$	$8.6 \pm 1.1$
Training (hour/week)	$20.4 \pm 1.4$	$19.0 \pm 1.5$	$23.4 \pm 2.2$	$20.9 \pm 1.7$
NRP (range of group)	3-80	1-24	1-11	1-80
IRPJC (range of group)	245-990	21-713	53-800	21-990

values are means  $\pm$  SD, G15, G16, G17 – each category of age; NRP- national ranking position, IRPJC – international ranking position (ITF) Values are not different significantly between groups

The revealed aerobic capacity is excellent in terms of the population base grading of the test, where the highest grade is accounted for  $\text{VO}_2\text{max}$  above  $54 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ . The average  $\text{VO}_2\text{max}$  is not only much higher than the gender and age-matched population standards, which are between  $39 - 45 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ,

[14,30] but also are superior to the respective recommendations of the International Tennis Federation for this age category and gender:  $2560 \text{ m}$  and  $51.5 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ . The specific  $\text{VO}_2\text{max}$  is age dependent. In early childhood  $\text{VO}_2\text{max}$  increases earlier in females but is of greater magnitude in males. Girls usually at-



tain the peak  $VO_2$ max at ages 11-13. Then, in contrary to boys, who maintain their peak for the next 5 -10 years,  $VO_2$ max tends to decrease progressively [10] that is linked to the accumulation of adolescent fat and low physical activity. The interesting finding in the present study is lack of significant differences in  $VO_2$ max among the age-matched groups (59,1±3.1; 61.7±4.1, and 58.0±5.6 mL·kg<sup>-1</sup>·min<sup>-1</sup>, G15, G16, G17 groups, respectively), despite a significant increase in body weight and Fat% (Table 1). Such profile of  $VO_2$ max is supposed to reflect the delayed growth spurt and may implicate delayed assessment of peak aerobic capacity. Prolonged longitudinal observation initiated before puberty are needed to confirm the hypothesis.

The position in the ITFJC was related to  $VO_2$ max, as shown by a significant negative correlation ( $r = -0,6822$ ;  $p = 0,0025$ ). It should be emphasized that this is probably the first evidence of the relationship between aerobic capacity and sport success among the adolescent female elite tennis players. Two earlier reports, where congruent conclusion were drawn, referred to adult men [2], or young boys [24]. Our observation is intriguing since a dominant pattern of exercise during tennis game or match consists in series of short bouts with a high involvement

of anaerobic metabolism. Compared to continuous running exercise at a similar oxygen output, tennis play was evidenced to highly involve glycolysis, glycogenolysis and phosphagen metabolism [9]. On the other hand, the aerobic metabolism rate is of crucial importance during the rest periods at a game for fast replenishment of the muscle phosphagen. Having diverse exertional intensities as tennis game does, efficient aerobic component enables players to maintain performance at effective level.

Average values of the anaerobic capacity parameters obtained from Wingate test are shown in Table 3. The Maximal Power (Wkg<sup>-1</sup>) and related Work Output (Jkg<sup>-1</sup>) were relatively low, compared to the reference of trained athletes (Maximal Power below 10 Wkg<sup>-1</sup>, Work Output below 200 Jkg<sup>-1</sup>) [29] and corresponded to those obtained by the untrained. There were no significant differences in Maximal Power and Work Output among the age-matched groups. In the whole group, the Maximal Power and Work Output were proportional to the anthropological indexes: BMI ( $r = 0.5190$ ,  $p = 0.0328$ ;  $r = 0.7191$ ,  $p = 0.0011$ ; respectively,  $n = 17$ ) and lean body mass (FFM;  $r = 0.4926$ ,  $p = 0.0445$ ;  $r = 0.5952$ ,  $p = 0.0118$ ; respectively,  $n = 17$ ), but not Fat% ( $r = 0.1546$ , and  $r = 0,3381$ , NS).

Table 3. Indexes of Wingate anaerobic test

Variable	G15 (n=6)	G16 (n=4)	G17 (n=7)	All (n=17)
Max Power (W·kg <sup>-1</sup> )	9.2±0.9	9.0±1.0	9.4±0.4	9.3±0.8
Work output (J·kg <sup>-1</sup> )	122.0±13.5	119.0±14.8	125.5±5.8	122.7±10.9
Time to max Power (s)	6.9±2.4	6.6±2.7	5.5±2.7	6.2±2.5
Time at max Power (s)	5.6±2.6	4.1±1.0	4.5±1.3	4.8±1.8
LA <sub>rest</sub> (mmol·L <sup>-1</sup> )	0.8±0.3	1.0±0.1	0.9±0.1	0.9±0.2
LA <sub>directly after Wingate</sub> (mmol·L <sup>-1</sup> )	9.6±2.2	9.6±2.6	10.7±2.6	10.0±2.4

values are means ± SD, G15, G16, G17 – each category of age

Procedure of Wingate test was followed in full-resistance conditions [32]. Consequently, the players reached the maximal power between 5th and 8th second and maintained it for the next 3-6 seconds. There were no significant differences in the time needed for assessment maximal power (Time to max Power) and duration of maintaining the peak power (Time at max Power) among the age-matched groups, although significant trend towards decreasing the both times with age were noted. Exclusively in G15 group Time to max Power was positively linked to BMI ( $r =$

0.8136,  $p = 0,0489$ ), FFM ( $r = 0.8558$ ,  $p = 0.0297$ ), and Fat% ( $r = 0.8207$ ,  $p = 0.0453$ ), whereas in the other groups there was irrelevant tendency toward a negative correlation. In each group Time at max Power was in somewhat inversely related to BMI, FFM, and Fat%, although the significant correlations were disclosed in the whole group for BMI ( $r = -0.6808$ ,  $p = 0.026$ , and Fat% ( $r = -0,5517$ ,  $p = 0.0220$ ), whereas in the particular age-matched groups the relevant correlations were observed in case of BMI in group G15 ( $r = -0.9706$ ,  $p = 0.0013$ ), and in case of Fat% in

group G17 ( $r = -0.8604$ ,  $p = 0.0129$ ). Neither between  $VO_2\max$  nor the international ranking position (ITFJC) and the indexes of Wingate test correlations were observed, as confirmed by irrelevant significance ( $p > 0.1$ ) of the correlation coefficients in the whole group and in particular age groups. Regular endurance training is known to induce an improvement of aerobic capacity. Depending on the mode of training, its duration and employed motion patterns, intense aerobic exercise is likely to compromise the maximal speed, agility, and sometimes in anaerobic capacity. Tennis training and game consist of short bouts of repetitive intervals, with use of high proportion of anaerobic metabolism, including high proportion of phosphagen utilization. Thus, the observed lack of correlation between anaerobic parameters obtained from Wingate test and  $VO_2\max$  is not surprising. On the other hand, adaptive responses to any training form in prepubertal children do not differentiate specific pathway of energy metabolism, so that training results in either increase in aerobic capacity or in anaerobic fitness [22]. Consequently in boys and girls at age 7-12 maximal oxygen uptake is closely related to maximal power output [1]. This was evidently not the case in our study: high aerobic capacity was associated with low anaerobic indexes. As revealed by regression analysis the important factor was somatic development, especially related to muscles (FFM). The higher BMI, FFM, the higher maximal power was generated, the longer time was needed to assess to maximal power output. Blood lactic acid (LA) concentration was virtually at a basal level ( $0.8 \pm 0.3$  to  $1.0 \pm 0.1$   $\text{mmol} \cdot \text{L}^{-1}$ ) prior to Wingate test. Metabolic response determined with the LA measured after the test was prominent (Table 3), and averaged from  $9.6 \pm 2.2$  to  $10.7 \pm 2.6$   $\text{mmol} \cdot \text{L}^{-1}$  in the particular age groups. The observed lactic response was lower than that reported in boys group [31] and corresponds to the conclusions of Jaworski [12], who reported lower maximal activities of glycolytic and glycogenolytic enzymes (glycogen phosphorylase, phosphofructokinase PFK and lactate dehydrogenase) in females. Although, the LA-response did not correlate to the anthropological parameters, the time of maintenance of maximal work output (Time at max Power), which reflects anaerobic endurance, inversely correlated to BMI, and Fat%. Interestingly, the lean body mass (FFM) did not seem to be much involved.

Concluding: The unexpected substantial body growth observed in the female group of the elite tennis players within the age range of 15 to 17 suggests a 2 -3 year delay of growth spurt. In terms of physical capacity,

aerobic capacity seems to be crucial for the temporal sport success indexed by the tennis federations ranking positions. The anaerobic indexes such as maximal power or maximal work output are apparently of minor importance. Anaerobic capacity of the elite female adolescent tennis players, which is highly involved in prolonged intermittent exercise of high intensity, is related to BMI and lean body mass. The appropriate control of the somatic stature is so prerequisite for the sport success and future outcome.

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## SUMMARY

### BODY COMPOSITION AND PHYSICAL CAPACITY OF ELITE ADOLESCENT FEMALE TENNIS PLAYERS

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The study was performed to evaluate relationships among the major anthropological parameters: (body

mass - BM, height, body mass index - BMI, lean body mass - FFM, proportion of fat mass - Fat%), physical capacity, and the tennis federations ranking position as an index of the temporal sport success. Seventeen elite female tennis players, divided into three age-matched groups (15, 16, and 17 yr) participated in this study. All the players had a national singles ranking (positions between 1<sup>st</sup>-80<sup>th</sup>) and in International Tennis Federation's Junior Circuit ranking (ITFJC; 21<sup>st</sup> to 990<sup>th</sup> position of ITF). Body composition was assessed via bioelectrical impedance. Maximal aerobic capacity (VO<sub>2</sub>max) was calculated from the distance covered in 12-min run test via Cooper's formula. Wingate test with lactate assay was used as an index of anaerobic capacity. There was a significant age-related trend for an increase in BM, height, FFT, and Fat%, associated with impressive shift of the anthropological indexes of body weight and height, assessed by the percentile chart analysis. The unexpected body growth spurt evidently observed between aged 15 and 17 is supposed to reflect a delay in somatic development, related to

extensive exercise load. Body composition did not correlate to the ranking positions. All tested tennis players revealed excellent aerobic capacity associated with poor indices of anaerobic fitness. The position in the tennis federations rankings correlated to VO<sub>2</sub>max but not with maximal power or maximal work output assessed by Wingate test. In the whole group the maximal power and work output were proportional to BMI and FFM, but not to Fat%. In conclusion, in light of the contradictory reports concerning a possible link between strenuous regular exercise performed by young children and adolescent elite sportsmen our data indicate a delayed growth spurt in the elite female tennis players to occur between ages 15 and 17. The other important finding in terms of prospective for future professional career is the evident link between aerobic capacity and ranking positions.

**Key words:** aerobic capacity, anaerobic capacity, tennis ranking, female, adolescence, Wingate test, BMI, lean body mass, somatic growth.

## РЕЗЮМЕ

### СОСТАВ ТЕЛА И ФИЗИЧЕСКИЕ ВОЗМОЖНОСТИ ЭЛИТНЫХ ТЕННИСИСТОК ПОДРОСТКОВОГО ВОЗРАСТА

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Целью исследования явилось определение взаимосвязи основных антропологических параметров (масса тела - МТ, высота, индекс массы тела - ИМТ, худоба, дефицит массы тела - ДМТ, удельный вес жира в массе тела - Fat%) с физическими возможностями и рейтингом по данным теннисных федераций (в качестве индекса временного спортивного успеха). В исследовании участвовали семнадцать элитных теннисисток, которые были подразделены на три возрастные группы (15, 16, и 17 лет). Национальный рейтинг - 1-80, рейтинг согласно Международной теннисной федерации - 21-990. Состав тела оценивался посредством биоэлектрического импеданса. Максимальная аэробная способность (VO<sub>2</sub>max) вычислялась по расстоянию, покрытому бегом за 12 минут, по формуле Коопер. Тест Wingate с определением лактата использовался как индекс анаэробной способно-

сти. Выявлена тенденция увеличения МТ, высоты, ДМТ, и Fat% с возрастом, что было связано со значительным изменением антропологических индексов массы тела и высоты, определяемых перцентильными таблицами. Неожиданный спурт роста, обнаруженный в возрасте между 15 и 17 годами, видимо, отражает предыдущую задержку соматического развития, связанную с тяжелой физической нагрузкой. Состав тела не коррелировал с рейтингом. Все теннисистки показали превосходные аэробные возможности, а анаэробные индексы были низкие. Рейтинги коррелировали с VO<sub>2</sub>max, однако не с максимальной мощностью или максимальной продукцией работы, оцененной тестом Wingate. Максимальная мощность и продукция работы были пропорциональны ИМТ и ДМТ, но не Fat%. В свете противоречащих сообщений следует отметить, что наши данные указывают отсрочен-



ный спурт роста у элитных теннисисток в возрасте между 15 и 17 годами. Еще одним значимым выводом является обнаружение очевидной связи между аэробными возможностями и рейтингом, что, безусловно, имеет значение для прогнозирования потенциальных спортивных успехов.

## რეზიუმე

სხეულის შემადგენლობა და ფიზიკური შესაძლებლობები ელიტარულ მოზარდ ჩოგბურთელ გოგონებში

<sup>1</sup>ევა ციემანი, <sup>2</sup>ეველინა სლედზიევსკა, <sup>3</sup>თომას გრუვიანი, <sup>3</sup>ენ ლ. გიბსონი, <sup>1,4</sup>თომას კ. ვიერზბა

<sup>1</sup>ვარშავის სოციალური და ჰუმანიტარული მეცნიერებების სკოლა, ფიზიოთერაპიის დეპარტამენტი, სოპოტი, პოლონეთი; <sup>2</sup>ფიზიკური განათლებისა და სპორტის აკადემია, ფიზიოლოგიის დეპარტამენტი, გდანსკი, პოლონეთი; <sup>3</sup>ნიუ მექსიკის უნივერსიტეტი, ჯანმრთელობის, ვარჯიშისა და სპორტული მეცნიერების დეპარტამენტი, ალბუკერკე, აშშ; <sup>4</sup>გდანსკის სამედიცინო უნივერსიტეტი, ფიზიოლოგიის დეპარტამენტი, პოლონეთი

კვლევის მიზანს წარმოადგენდა ძირითად ანთროპოლოგიურ პარამეტრებსა (სხეულის მასა - სმ, სიმალღე, სხეულის მასის ინდექსი - სმი, სიგამხდრე, სხეულის მასის დეფიციტი - სმდ, სხეულის მასაში ცხიმის წილი - Fat%), ფიზიკურ შესაძლებლობებსა და ჩოგბურთის ფედერაციის რეიტინგულ პოზიციას (როგორც დროებითი სპორტული წარმატების ინდექსის) შორის ურთიერთდასაბუთებულების დადგენა. კვლევაში ჩართული იყო 17 წარმატებული ჩოგბურთელი გოგონა, რომლებიც განაწილებული იყვნენ სამ ასაკობრივ ჯგუფში (15, 16 და 17 წელი). ყველა ჩოგბურთელს მინიჭებული ჰქონდა ეროვნული რეიტინგი (პოზიცია 1-სა და 80-ს შორის) და საერთაშორისო ჩოგბურთის ფედერაციის მიერ მინიჭებული რეიტინგი იუნიორთა შორის (პოზიცია 21-სა და 990-ს

შორის). სხეულის შემადგენლობა შეფასდა ბიოლექტრული იმპედანსის მეშვეობით; მაქსიმალური აერობიკული შესაძლებლობა (უნარი -  $VO_{2max}$ ) - 12 წთ-ში გარბენით დაფარული დისტანციის ტესტით, რისი გამოთვლაც ხდებოდა Cooper-ის ფორმულით.

Wingate-ს ტესტი ლაქტატის ანალიზთან ერთად გამოყენებული იყო, როგორც ანაერობული შესაძლებლობის ინდექსი. დადგენილი იქნა სმ-ის, სიმალღის, სმდ-ის, ცხიმის ხვედრითი წონის ასაკთან დაკავშირებული მატების ტენდენცია, რომელიც ასოცირებული იყო სხეულის მასისა და სიმალღის ანთროპოლოგიური ინდექსის გამოხატულ ცვლილებებთან (შეფასებული პერცენტული ცხრილებითა და სქემებით). სხეულის სიმალღეში ზრდის სწრაფი მატება შეინიშნებოდა 15 და 17 წელს შორის ასაკში, რაც სავარაუდოა, რომ განპირობებული იყო მანამდე არსებული სომატური განვითარების შეფერხებით და დაკავშირებული იყო მნიშვნელოვან ფიზიკურ დატვირთვასთან ვარჯიშის დროს. სხეულის შემადგენლობის მაჩვენებლები არ იყო კორელაციაში რეიტინგულ პოზიციასთან. ყველა სპორტსმენმა გამოავლინა საუკეთესო აერობული შესაძლებლობები, ასოცირებული დაბალ ანაერობულ მაჩვენებლებთან. რეიტინგული პოზიცია კორელაციურ კავშირში იყო  $VO_{2max}$ , განსხვავებით Wingate-ს ტესტით შეფასებულ მაქსიმალურ სიმძლავრესა და მუშაობასთან. ყველა ჯგუფში მაქსიმალური სიმძლავრისა და მუშაობის მაჩვენებლები პროპორციული იყო სმი და სმდ, მაგრამ არა სხეულის მასაში ცხიმის წილის. ურთიერთგამომრიცხავი შრომების გათვალისწინებით ჩვენი მონაცემები მიუთითებს ზრდის დაგვიანებულ სპურტზე 15 და 17 წელს შორის ჩოგბურთელ გოგონებში. შემდგომი პერსპექტიული პროფესიული კარიერის წინასწარ განსაზღვრისათვის მეტად მნიშვნელოვან შედეგს წარმოადგენს აერობიკულ შესაძლებლობებსა და რეიტინგულ პოზიციას შორის სარწმუნო კავშირის აღმოჩენა.



## VARIABLE PROFILE OF INDIVIDUAL HEART RATE RESPONSES TO COLD WATER IMMERSION APNEA IN HEALTHY LATE ADOLESCENT MEN

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The diving reflex is a cardiorespiratory response routinely used by marine mammals for diving in water. Evidence from 3000-year-old Assyrian drawings have shown that men have practiced diving from immemorial time. The ancient divers would hold breath and dive underwater to collect pearls or catch fish. At modern times, one of the first freediving competitions was held in 1911 when a Greek fisherman, Yorgos Haggi Statti, dived more than 77 meters. Actually, the deepest officially recorded free diving attempt was more than 200 meters and the longest duration of static, breathless apnea was 11:35 min. The diving response consist of bradycardia, peripheral vasoconstriction with a preferential redistribution of blood to vital organs: brain and heart, and is triggered by an activation of the peripheral chemoreflex in conditions of hold breathing [8,12]. The neural mechanism of the response is somehow paradoxical with a simultaneous increase in the both sympathetic and parasympathetic components of the autonomic cardiovascular drive. Bradycardia is mediated by vagal activation while peripheral vasoconstriction that increases blood pressure and shunts blood from the extremities to the body's core is evoked by activation sympathetic fibers. The evoked bradycardia and blood shift are potentiated by cooling of the face, in particular the vestibule of the nose, which is to activate the nerve endings and receptors of the trigeminal nerve [8].

The adaptive benefit of the response is believed to improve survival in near-drowning [13] and more commonly in nonspecific hypoxic conditions [8]. It has been generally accepted that the vagally mediated complex response: bradycardia, apnea, and selective vasoconstriction, provides protection against drowning for babies during underwater birth [21]. Cooling face and/or breath-holding maneuvers used to be recommended to terminate paroxysmal junctional tachycardias [18]. Reproducibility of the cardioinhibitory effect of the human diving response allows to employ diving and cooling procedures in laboratory exercises in high school and university courses [11].

On the other hand, vagal inhibition of the cardiac pacemaker and the heart conduction system combined with accentuated sympathetic drive to the heart ventricles is of high potency to induce cardiac arrhythmias. The diving reflex is frequently considered as a pathogenic factor of sudden infant death syndrome (SIDS). It has been reported that rapid cooling face with cold water or plunging into cold water can provoke severe cardiac deceleration with involvement of central vagal nuclei [17]. The momentary difficulties or even inability to breathe while unexpectedly experiencing a very cold wind blowing onto face on a winter day is one manifestation of the apnea reflex resembling diving response. Adults with cardiac insufficiency or babies in this situation can be at particular risk because of serious cardiac deceleration to happen more likely. There has been considerably increasing interest in accidents related to cold-water immersion and drowning since related fatal incidents are among the major causes of sudden death of both children and adults in regions located at the seaside. For all causes of death in teenagers in USA, the water-related incidents are exceeded only by motor vehicle accidents and cancer. Severe drowning or near-drowning accidents were reported to take place mostly in young men in a prevalent age group between 16 and 20 years. Most of victims were reportedly to be good swimmers or divers and 50% accidents occurred in swimming pools. A variety of breathhold games and diving competitions, quests for greater depths and longer lasting apneas, training procedures aimed to increase oxygen reserve, have recently evolved, bringing the participants at increased high of life-threatening events. The extent of evoked arrhythmias is difficult to predict due to high interindividual variability. The diving response is age- and experience dependent, and is highly pronounced in children 4 -12 month of age, when it have survival value during hypoxic episodes proximal to birth [7,23]. The heart rate response weakens with advancing age and is more marked among habitual breath-hold divers than nondivers [23]. Less is known about the cardiac response to diving in teenagers who are mostly

prone to unexpected diving experiments and related complications.

The study was performed to investigate the heart rate response to controlled breath-hold diving in cold water in young healthy late adolescents.

**Material and methods.** Twenty healthy male volunteers, physiotherapy students were studied. Age ( $18,9 \pm 0,9$  yr), weight ( $72.0 \pm 10,5$  kg), and height ( $177.0 \pm 6,1$  cm) ranged 17.5-20.4 yr, 59.0-94.0 kg, and 165-188 cm, respectively. All subjects declared to carry on regular physical activity lasting at least 2 hr daily, six of them played regularly football at a level of amateur competition, but all had no previous experience with professional sport, prolonged diving or breath holding. The experimental protocol was conducted in conformity with the principles of the Declaration of Helsinki and was based on a laboratory teaching experiments performed at the Medical University of Gdansk for more than 40 years. All subjects signed their informed consent after receiving a detailed description of the procedure, including a description of potential risks.

All tests were conducted at room temperature 22-25°C. The subjects was leaning over the lab bench with elbows resting on the lab bench and the head down. ECG electrodes were first placed on a both arms and ankles to assess the classical ECG leads and were connected to a conventional 3-channel ECG recorder (Aspel, Poland). After 5 min rest, ECG signal was recorded at 50 mm/s speed. Thereafter each subject was instructed how to perform the experiment. Cold tap water (8-10°C) was poured into a plastic container positioned against the subject. To examine the effect of breath-holding diving apnea on heart rate (HR), the subject was asked to hold breath, immerse his face into water and to persist in such position as long as possible. ECG was continuously recorded prior to and during water immersion. ECG recordings were enlarged for possibly accurate assessment of RR intervals to obtain beat-by-beat HR and also for identification of P waves and PR intervals. Time series of beat-to-beat HR calculated from RR intervals were analyzed with use GraphPad Prism software (GraphPad Software, Inc., Tulsa, USA) for curve fitting. A decreasing function with a single phase exponential or two-phase exponential decay curve were computed. The quality of curve fitting was judged by calculating the coefficient of determination

( $r^2$ ). Fitting the curves started from the maximum HR ( $HR_{max}$ ) and ended with points at which HR stabilizes ( $HR_{stab}$ ). In some cases lower HR values exceeding the general HR trend were eventually noted ( $HR_{min}$ ) during the apnea recording. For the monoexponential decay the equation:  $Y = Span \cdot \exp(-\tau \cdot X) + Plateau$  was employed, that starts at  $Span + Plateau$  ( $HR_{max} - HR_{stab}$ ) and decays to plateau ( $HR_{stab}$ ) with a rate constant  $\tau$ . Whenever  $r^2$  calculated from the monoexponential decay curve was lower by more than 0,05 from the plot of the two-phase curve the latter was considered appropriate. For the two phase HR decline the equation  $Y = Span_1 \cdot \exp(-\tau_1 \cdot X) + Span_2 \cdot \exp(-\tau_2 \cdot X) + Plateau$ , that starts at  $Span_1 + Span_2 + Plateau$  and decays to Plateau with rate constants  $\tau_1$  and  $\tau_2$ .

All values are expressed as mean  $\pm$  SD. For comparisons between two groups representing the monoexponential HR decline at  $\tau$  and also the two-phase HR decay curves at  $\tau_1$  and  $\tau_2$  Student t test was employed. Relationships between pairs of variables were tested with Pearson linear regression method.  $P < 0.05$  was considered significant.

**Results and their discussion.** All subjects but one completed the protocol. In one case the experiment was rapidly terminated by the laboratory staff in 40.4 s of diving when a pair of heterogenous ventricular extrasystolic beats were observed, so that values of  $HR_{stab}$ , diving time ( $t_D$ ),  $t_{HRstab}$  were not assessed in this case for further analysis. Mean values of the major variables are shown in Table. Average diving time ( $t_D$ ) was  $77.5 \pm 10.5$  s, ranging from 61.7 to 95.4 s. For majority of untrained people holding breath for several seconds is easy, although prolonged apnea, lasting more than 1 min usually makes problem. The time score in this study correspond to average oxygen reserve remained in lungs for some time during apnea and its pool in red blood cell hemoglobin and muscle mioglobin.

Bradycardia occurred for every subject. In some earlier reports diving not always induced a reliable heart rate reduction [11]. Heek et al. observed that in only about 66% volunteers HR was reduced after submersion [10]. Diving induced bradycardia is in most literature data a regular reflex response to decrease pulse rate in a normal individual by 10 to 30 percent and sometimes by more than 50 percent in professionally trained free divers [26]. Here, the average HR reduction from the basal level ( $HR_0$ ) was  $35.6 \pm 12.6\%$ , ranging from 10.7 to 54.6%. Relatively big response

observed in the present study may be related to a relevant temperature contrast during immersion. Cool water is known to promote the cardiodepressive reaction, which is highly dependent on stimulation of superficially located nerve endings of ethmoidal branches of the trigeminal nerve [22]. Tremendous asymptomatic bradycardia (temporarily below 6 beats/min) induced by apnea with cold-water face immersion has been previously documented [14]. Quite long duration of the voluntary apnea seems to play a minor role as heart rate stabilized ( $t_{HRstab}$ ) almost 23 s prior to termination of an average water

immersion (Table). Maximal bradycardic response was reported to occur before 40 s of breath-hold apnea in both adults and 11-14 yr old children [9,20]. Highly pronounced diving reflex which is to slow temporary metabolic demands, and preferentially provides brain with blood supply, often explains why children who have been submerged in cold water long periods of time have survived. In general, such adaptation has not been attributed to late adolescents but it may also be protective in some significant extent to lengthen the time before the onset of serious hypoxic damage.

Table. Characteristics of the basal variables related to the immersion apnea test

Variable	All N=20	Group I N = 8	Group II N = 12	P I vs. II
BMI (kg/m <sup>2</sup> )	22.8±2.9 (18.8-28.4)	23.5±3.0 (18.8-27.8)	22.3±2.8 (18.3-28.4)	NS
HR <sub>0</sub> [min <sup>-1</sup> ]	74.7±5.3 (66.4-85.9)	77.5±4.8 (71.5-85.9)	72.8±4.9 (66.4-81.0)	0.045
HR <sub>ini</sub> [min <sup>-1</sup> ]	92.2±15.0 (73.9-125.0)	96.9±15.5 (79.0-125.0)	89.0±14.6 (73.9-117.7)	NS
Diving time (t <sub>D</sub> ) [s]	78.0±10.5 (61.7-95.4)	76.6±11.1 (61.7-93.0)	78.8±10.6 (62.7-95.4)	NS
HR <sub>max incr</sub> [min <sup>-1</sup> ]	107.8±18.0 (83.6-150.7)	107.5±20.1 (83.6-150.7)	108.1±17.5 (84.3-140.5)	NS
Δ (HR <sub>max incr</sub> – HR <sub>0</sub> ) [min <sup>-1</sup> ]	33.2±16.8 (10.0-68.8)	29.9±18.8 (10.8-68.8)	35.3±15.9 (10.0-59.8)	NS
time HR <sub>0</sub> (t <sub>HR0</sub> ) [s]	15.5±10.3 (0.0-43.4)	20.7±14.3 (0.0-43.4)	12.1±4.5 (4.9-17.8)	NS 0.0636
HR <sub>stab</sub> [min <sup>-1</sup> ]	47.7±9.0 (36.3-65.0)	50.6±10.3 (39.0-65.0)	45.9±8.1 (36.3-57.8)	NS
Δ (HR <sub>stab</sub> – HR <sub>0</sub> ) [min <sup>-1</sup> ]	22.2±21.4 (-5.0-82.0)	30.5±25.2 (-5.0-82.0)	16.7±17.5 (0.1-48.9)	NS
time HR <sub>stab</sub> (t <sub>HRstab</sub> ) [s]	55.2±16.1 (19.5-77.8)	53.8±14.4 (36.7-77.8)	56.0±17.6 (19.5-77.8)	NS
τ [s <sup>-1</sup> ]	22.5±10.3 (12.5-45.2)	31.3±11.4 (15.3-45.2)	16.6±2.8* (12.5-20.1)	0.00043
τ <sub>1</sub> [s <sup>-1</sup> ]			10.3±4.2 (4.6-20.3)	
τ <sub>2</sub> [s <sup>-1</sup> ]			25.5±10.1 (11.3-42.5)	

Abbreviations: HR<sub>0</sub> – basal heart rate; HR<sub>ini</sub> – HR at the onset of immersion; Diving time – the overall time of breath-hold immersion; HR<sub>max incr</sub> – maximal HR at the onset of immersion; t<sub>HR0</sub> – time from the onset of immersion to assessment of HR<sub>0</sub> after the initial increase in HR; HR<sub>stab</sub> – stabilized HR value reflecting maximal bradycardic response; t<sub>HRstab</sub> – time from the onset of immersion to the final HR stabilization during the apnea; τ<sub>1</sub>, τ<sub>2</sub> – constant rates of HR of the two-phase exponential HR decrease.

\*In group II the two-phase exponential decay curve is best estimation of the function of HR decrease, although the coefficients of determination  $r^2 > 0.7$  for the monoexponential function was also significant and so τ from such model was used for the comparison

The onset and time course of bradycardia is influenced by many factors such as water temperature, lung volume, physical conditioning, preceded hyperventilation, body movements and body position in the water and psychological status.

The mean onset latency ( $t_{HR0}$ ), assessed by time from the onset of immersion to the beginning of HR reduction ( $HR_0$ ; Table) was  $15.5 \pm 10.3$  s (range 0-43.4s), whereas the maximal bradycardia ( $t_{HRstab}$ ) was seen at  $55.2 \pm 16.1$  s, ranging from 19.5 to 77.8 s. The latter was evidently longer from the average 34.7 s responses described originally by Guyton in older individuals [9]. The duration of latency depends on a reference baseline HR value. In this study an average HR recorded at least 5 min prior to the apnea, in a possible non-embarrassing conditions was taken as reference. The point is that majority of volunteers exhibited a gradual increase in HR while being instructed about the diving procedure just before its beginning, so that there was no reliable reference values at the onset of apnea. Pre-immersion or pre-breath-holding increase in HR has been already described in adults [15,26]. Anticipating the dive is supposed to transiently facilitate the sympathetic drive to increase HR. Such early HR acceleration have also been reported for diving mammals [3].

In most subjects the pre-immersion increase in HR kept increasing within the first seconds of immersion to reach in  $3.2 \pm 3.0$  s (range 0-9.2 s) the maximal HR ( $HR_{max}$ )  $33.2 \pm 16.8$   $\text{min}^{-1}$  higher from  $HR_0$  (Table). The observed initial increase in HR (up to  $108.1 \pm 7.5$   $\text{min}^{-1}$ ) means average  $44.5 \pm 21.8\%$  gain from  $HR_0$ . The response was twice as big as those reported in the previously trained 11-14 year-old group, and even much more higher than in adults [27]. The observed agitation would rather be expected in younger naive individuals in whom fear and facial stimulation with cool water might extensively stimulate an initial transient tachycardia [20,5].  $HR_{max}$  and latency ( $t_{HR0}$ ) determined the bradycardic response as shown by significant inverse correlation with maximal decrease of HR ( $r = -0.6575$ ;  $P = 0.02$  and  $r = -0.5807$ ;  $P = 0.048$ , respectively). This finding is compatible with the assumption that the higher metabolic rate, the faster hypoxia develops to evoke more pronounced reflex cardioinhibitory response. It has been suggested that any excitation wherever comes from: emotions, exercise, etc., resulting in vagal inhibition and a increase of sympathetic outflow, facilitates faster and marked development of bradycardia [3,6,14,23]. More pro-

nounce diving response has been evidenced during exercise than during rest [26,28]. Vagal inhibition of atrioventricular conduction combined with sympathetically induced enhancement of automaticity in other secondary latent pacemakers would highly increase risk for ectopic beats when apnea was preceded by exercise [25]. Consistently, the remarkable sudden drop in HR from more than 100 to about 40 beats/min associated with the occurrence of potentially dangerous pair of heterogenic ventricular ectopic beats was observed in one of our subjects (Fig. 2; #17) who exhibited the highest increase in HR at the onset of the water immersion and whose diving attempt was terminated at the moment.

A trend of HR changes prior to and during water immersion is depicted in Fig.1.

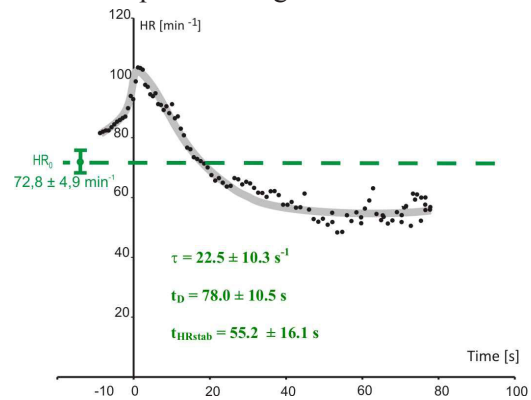


Fig. 1. Averaged time course of beat-to-beat heart rate before and during the apneic water immersion green dot and the respective dashed line – represent mean  $\pm$  SD of the basal HR ( $HR_0$ ) at least 5 min before diving, black dots are averaged values of HR at given time; grey line represents an averaged trend of HR before and during the immersion.

$\tau$  - constant rate of HR decrease described by the monoexponential function;  $t_D$  - time of immersion,  $t_{HRstab}$  - time from the onset of immersion to the final HR stabilization during the apnea

The impressive increase in HR at the onset of the apnea was turned to the bradycardic response to reach a lower HR limit in  $55.2 \pm 16.1$  s of the immersion. The averaged curve of HR decline well fit to monoexponential decay with a rate constant  $\tau$   $22.5 \pm 10.3$   $\text{s}^{-1}$ . The kinetics of the response was somehow slower from the averaged bradycardic response calculated in the most recent metanalysis, included 205 subjects, in the age range 19 -25, who performed trials under apnea and face immersion conditions, where HR monoexponentially decreased with  $\tau = 10.4$   $\text{s}^{-1}$  [4].



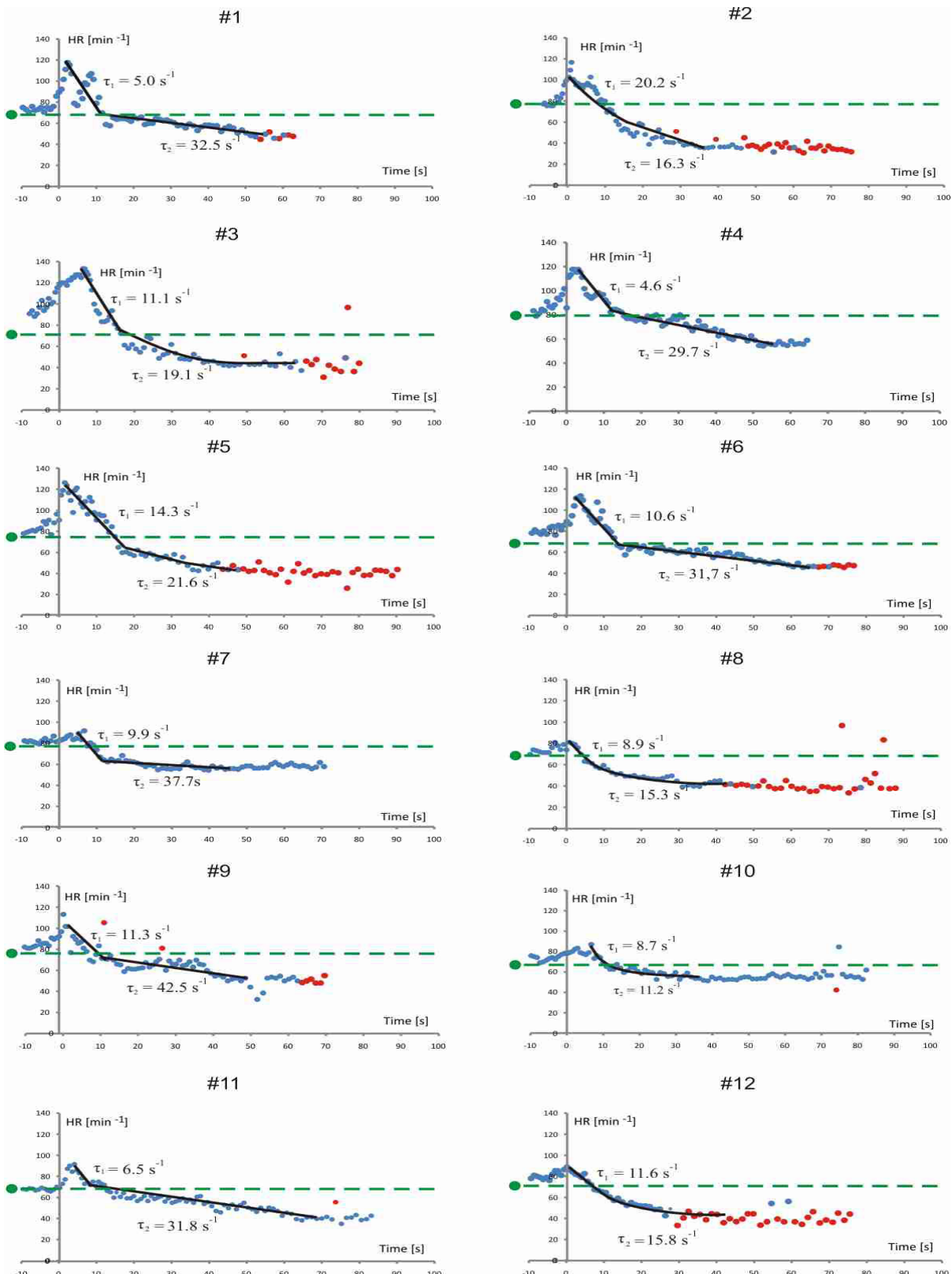


Fig. 2. Selection of the individual time courses of beat-to-beat heart rate before and during the apneic water immersion, where the bradycardic response is a monoexponential function green dots and the respective dashed line – represent mean  $\pm$  SD of the basal HR (HR<sub>0</sub>) at least 5 min before diving, black dots are averaged values of HR at given time; grey line represents an averaged trend of HR before and during the immersion.  $\tau$  - constant rate of HR decrease described by the monoexponential function. Blue dots represent sinus rhythm, whereas red dots represent extrasystolic beats or junctional rhythm



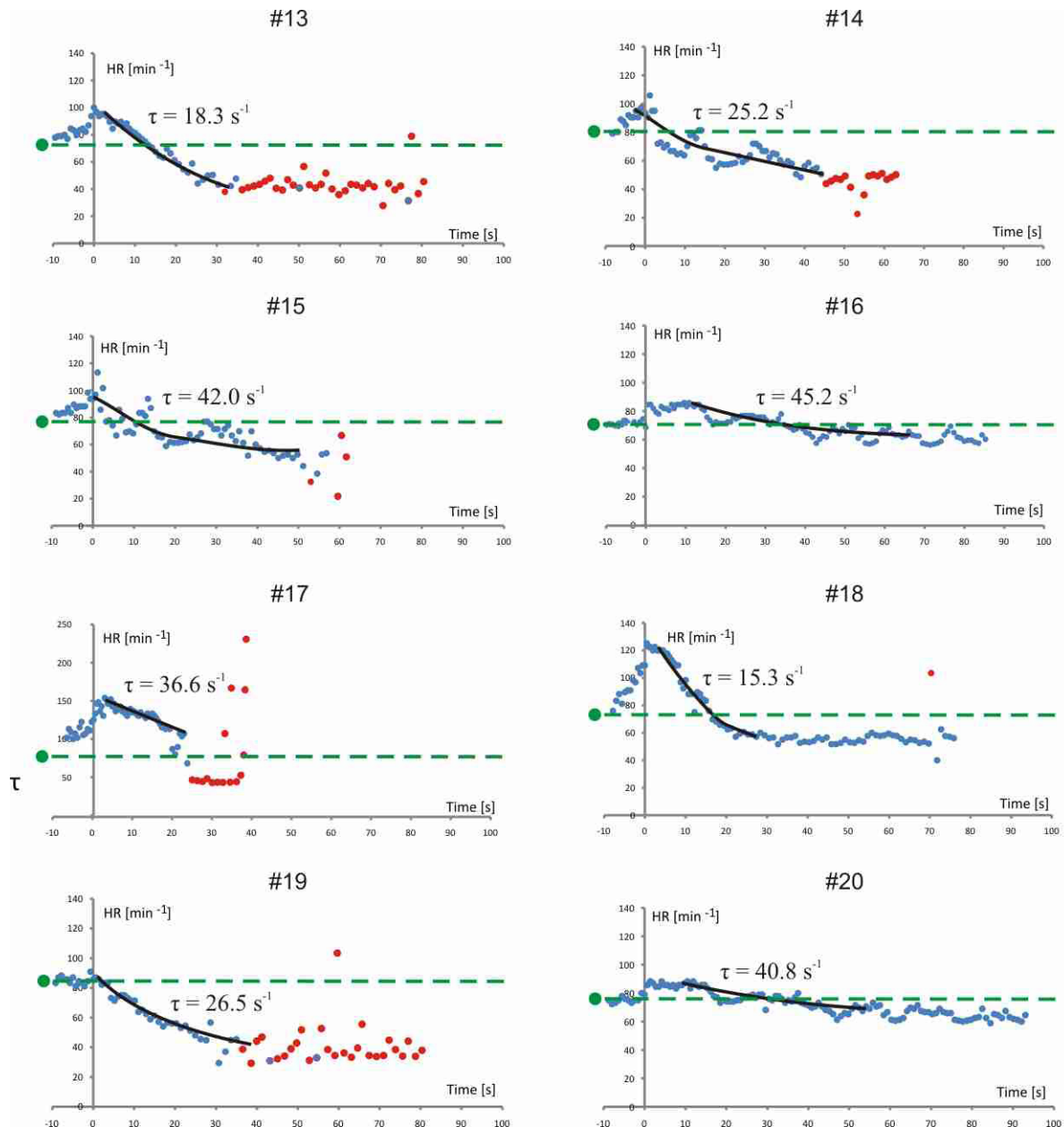


Fig. 3. Selection of the individual time courses of beat-to-beat heart rate before and during the apneic water immersion, where the bradycardic response is the two-phase exponential function with two rate constants  $\tau_1$  and  $\tau_2$ , green dots and the respective dashed line – represent mean  $\pm$  SD of the basal HR ( $HR_0$ ) at least 5 min before diving, black dots are averaged values of HR at given time; grey line represents an averaged trend of HR before and during the immersion. Blue dots represent sinus rhythm, whereas red dots represent extrasystolic beats or junctional rhythm

The point is that the diving response is highly variable among humans [1]. Baranova et al. have underlined interindividual differences and classified cardiovascular responses to diving into four subsets: over-reactive, reactive, nonreactive, paradoxical [2]. A high quantitative differences were also noted in this study as shown by relatively high range of the obtained variables (Table), such as: HR at the onset of apnea ( $HR_{ini}$ ), maximal HR increase at the onset

of immersion ( $HR_{max\ incr} - HR_0$ ), time from the onset of apnea to assessment of  $HR_0$  after the initial HR increase ( $t_{HR0}$ ), time of HR stabilization at a lower limit ( $t_{HRstab}$ ). The individual HR responses are shown in Figs 2 and 3.

In 15 (75%) subjects the negative chronotropic effect was not immediate. The rapid onset of the cardioinhibitory response exhibited subjects #1, #6, #7 (Fig. 2)

and also #16 and #20 (Fig.3). For majority of subjects, the response needed some latency to take place. In 12 volunteers (60%), the time course of HR decline was more complex than the fitted monoexponential equation; curve the coefficient of determination  $r^2$  calculated from the monoexponential equation was significantly lower from that assessed by function of two phase exponential decay (Fig. 2; group II, subjects #1 - #12). The obtained data are inconsistent with the averaged data from the recent metaanalysis published by Caspers et al [4], although 8 volunteers (Fig. 3; group I, subjects #13 -20) exhibited the curve of decrease in HR fitted to the monoexponential function, which corresponds to those described in the above metanalysis. The problem in curve fitting is defining limits of the response for the given curve, and in particular inclusion or exclusion of the time delay from the onset of apnea to the beginning of systematic decrease in HR. In this study, the latency was taken into account for fitting the individual's curve. This was not the case when all data were summarized (Fig. 1) where the monoexponential curve fitting is apparently appropriate. Two phases of the negative chronotropic response has been already identified by Paulev et al. [19]. The initial fast parasympathetic response was reported to depend on the input from the high pressure baroreceptors, whereas the sympathetic efferent activity was inflicted in the second phase of HR reduction of lower dynamics. As shown in Table, in Group I (monoexponential HR decay) basal HR ( $HR_0$ ) was higher with a tendency towards longer time of the initial HR increase ( $t_{HR0}$ ), and lower dynamics of the bradycardic response. The latter comparison was based upon the rate constant  $\tau$  calculated for a monoexponential function. Although such a way of curve fitting was not the best assessment of the HR decrease in Group II, the coefficients of determination  $r^2$  calculated from the monoexponential decay model were higher than 0.7 in all subjects of Group II, so it should not be neglected, taking into account significance level  $P < 0.001$  (Table) for the differences between the both groups. The exponential HR decay in group II was more consistent than displayed in Group I. In group II only subject #9, and in lesser extent subjects #12 and # 14 exhibited remarkable fluctuations of HR at the early phase of the HR decrease, whereas a wave form of a time course of the bradycardic response was evident at early its stage in subjects #3, #4, # 8, and in particular in #2 of Group I (Fig. 3). Moreover, all individuals of Group I, except #6, exhibited pronounced fluctuations of HR in the

late stage of the applied immersion apnea. Hypothetically, the slower (Table), one-phase kinetics of the HR decrease induced by water immersion, that according to Paulev et al. [19] would be attributed to a lower inputs from high pressure baroreceptors, may result in more unstable HR cardioinhibitory response.

A common feature of a human diving response is the combination of bradycardia with occurrence of ectopic beats, disturbances of atrioventricular (AV) conduction, and arrhythmias. The both groups revealed similar occurrence of heart rhythm abnormalities. A few episodes of supraventricular premature beats were recorded in 8 subjects (40%), while ventricular ectopic beats (VEB) were found in 4 (20%) during the decrease in HR, especially at the late phase of the apnea. In one subject (17#, Fig. 3) the apneic trial was terminated immediately after the occurrence of pair of heterogenic VEBs. Transient episodes of AV blocks of the first-degree (with PR interval up to 310 ms) occurred in 6 volunteers (30%). Three of them displayed also the Mobitz I second-degree AV block characterized by a progressive prolongation of the PR interval, that eventually turned to a regular junctional rhythm. In 12 subjects sinus rhythm was interfered with an escape junctional rhythm (red dots in Figures 2 and 3). The average onset of the junctional rhythm was at HR  $42.8 \pm 4.1$  beats/min, in  $43.5 \pm 13.1$  s of the apnea. RR intervals longer than 2 s: 2.36 s and 2.76 s were recorded incidentally in two subjects. Vagal inhibition of atrioventricular conduction coincided with sympathetically induced enhancement of automaticity in the ventricular latent pacemakers is of increased risk for triggering critical cardiac events. Cardiac rhythm disturbances were first recorded in pearl divers by Scholander et al. in 1962 [24] and seem to be more prevalent in dives in cool water [6]. Some of the reported fatal cases were undoubtedly of cardiac origin, which, when due to arrhythmia, were unexplainable from autopsy findings and therefore were recorded as "drowning". Risks connected with breath-hold diving is not easy to estimate due to great individual variability and dependence of current disposition and diving conditions [14]. The relevant heart rate response variability was confirmed in the present study in which one subject untimely terminated the protocol. Cardiac arrhythmias were previously reported to occur immediately after cold water immersion [16], but in the present study this was not observed at the early phase of the apnea, but later, after 30 s of the trial.

In conclusion, young healthy volunteers, between age 17.5 and 20.4, not accustomed to diving, nor involved in regular training, exhibited an impressive diving response characterized by non-uniform pattern of the HR decrease and a high interindividual variability. The increase in HR was followed by its gradual decrease to a final limit of the response. The evoked bradycardia and the dynamics of its development was related to the initial, anticipatory excitation. Disturbances of heart rhythm were observed, in one case the recorded pair of ventricular ectopic beats looked severe. The unquestionable potency of late adolescents towards diving challenges, accompanied with a vigorous emotionally driven initial cardioexcitation, and a relevant vulnerability for arrhythmias, should imply some educative and safety measures to prevent from fatal outcomes.

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## SUMMARY

### VARIABLE PROFILE OF INDIVIDUAL HEART RATE RESPONSES TO COLD WATER IMMERSION APNEA IN HEALTHY LATE ADOLESCENT MEN

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Holding breath combined with immersion of face in cool water induces diving reflex consisting in bradycardia, peripheral vasoconstriction, and preferential redistribution of blood to the vital organs. The individual responses are variable, highly expressed in young children to weaken with age. Detailed assessment of the cardiac response to diving in late adolescents who are mostly prone to unexpected diving experiments and related complications are of practical importance. The study was performed to investigate the heart rate (HR) response to controlled breath-hold diving in cold water in young healthy late adolescents aged 17.5 - 20.4. Twenty volunteers performed a procedure consisting in immersion of face in cold water during possibly long breath-holding. Beat-to-beat HR was assessed from the continuous ECG recording. Average diving time ( $t_D$ ) was  $77.5 \pm 10.5$  s, ranging from 61.7 to 95.4 s. Apnea and face immersion induced a biphasic response: an increase in HR was followed by its

gradual decrease to reach a final limit of the response  $47.7 \pm 9.0$  beats/min at  $55.2 \pm 16.1$  s of dive. Within a variable time course of the evoked responses, two patterns of the HR decrease were distinguished: monoexponential decay functions fitted best for 8 (40%) subjects with a constant rate  $\tau$   $31.3 \pm 11.4$  s<sup>-1</sup>, whereas the 60% majority displayed a two phase negative chronotropic effect with constant rates:  $\tau_1$   $10.3 \pm 4.2$  s<sup>-1</sup> and  $\tau_2$   $25.5 \pm 10.1$  s<sup>-1</sup>. The initial, anticipatory excitation influenced the HR response: the higher was the initial HR increase, the more pronounced was bradycardia. Disturbances of heart rhythm were observed in majority of subjects: supraventricular ectopic beats (40%), ventricular beats (20%), I-degree AV block (30%), II-degree Mobitz I block (15%), junctional rhythm (60%). In one case pair of ventricular ectopic beats looked severe and the trial was rapidly terminated. In conclusion, the unquestionable potency of late adolescents towards diving challenges, accompanied with a vigorous emotionally driven initial cardioexcitation meets a relevant vulnerability for arrhythmias.

**Key words:** diving response, bradycardia, water immersion, arrhythmia, adolescence

## РЕЗЮМЕ

### ВАРИАБЕЛЬНЫЙ ПРОФИЛЬ ИНДИВИДУАЛЬНЫХ ИЗМЕНЕНИЙ СЕРДЕЧНОГО РИТМА ПРИ АПНОЭ, ВЫЗВАННОМ ПОГРУЖЕНИЕМ В ХОЛОДНУЮ ВОДУ, У ЗДОРОВЫХ ЮНОШЕЙ СТАРШЕГО ВОЗРАСТА

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Задерживание дыхания при одновременном погружении лица в холодную воду вызывает рефлекс ныряния, вследствие чего возникает брадикардия, периферическая вазоконстрикция с преимущественным перераспределением крови к жизненно важным органам. Индивидуальные изменения различны, более сильно выражены у маленьких детей и ослабевают с возрастом. Крайне важно детально оценить сердечные изменения при нырянии у подростков старшего возраста, склонных к неожиданным экспериментам с ны-



რანიემ, ვიზვიაოუიშმ სოოთვსთვუიშმე ოსლოჟნენი. ისსლეოვანი ბოლო ვრეოვენი ს ცელო იზუოენი იზენენი სეროენო რიშმ (CP) პრი რეგულირეოემოი ჯადრჟკე დიშანიი პრი ნირიანიი ვი ხოლოდნუო ვოუი უ იოიშეი. დვადციი დობროვოლციე, ვი ვოიშტე ოთ 17,5 დო 20,4 ლეი, პრევილი პროოედურე, სოსთიშუი იზ პოგრუჟენი ლიეი ვი ხოლოდნუო ვოუი ს ჯადრჟკეი დიშანიი კაკ მოჟიო დოლშე. იზენენი CP ოპრეოდეილი პოსრეოდიშმ ნეპრერუივი ჯიპისი ოკგ. სრეოენე ვრეიი ნირიანიი ( $t_p$ ) რავნიოლშე 77,5±10,5 სეკ, ვარიირეი ვი პრეოდეილი ოთ 61,7 დო 95,4 სეკ. აპნოეი პოგრუჟენი ლიეი ივლიეილი პრიოინოი ბიფიშნი სდვიგო: ჯი ივლიეილი სეროენი CP სლეოვოლო ეოი პოსტეპენიეი სნიჟენი დო დოსთიჟენი ოკონოიშნი გრანიციი იზენენი - 47,7±9,0 უდარ/მინ ნი 55,2±16,1 სეკ ნირიანიი. ბოლო ვი დეილენო დვი პატერნი სნიჟენი სეროენი CP: მონოეკსპონენიციილნი უმენშენი ფუნკციი ბოლშე პოდოშო 8 (40%) უოიშტიკამ ს პოსთიანნი რიშმ  $\tau$  - 31,3±11,4

სეკ<sup>-1</sup>, თოგა კაკ ბოლშინიშმე (60%) პრევილი დვუიფიშნი ოტრიოიშნი ხრონოტროპიოეი აფექტი ს პოსთიანნი რიშმ:  $\tau_1$  - 10,3±4,2 სეკ<sup>-1</sup> ი  $\tau_1$  - 25,5±10,1 სეკ<sup>-1</sup>. ნიოიშნი, ოჟიოდეიეი ვოზბუჟენი პოვლიეილი ნი პოკიშტეი სეროენი CP: კემ ვიშე ბოლო ნიოიშნი სეროენი CP, თემ სილშენე ბოლო ვი რევილენი ბრადიკარდიი. ნარუშენი სეროენი რიშმ ბოლო ოტმეოენი უ ბოლშინიშმე უოიშტიკამ: ნიჟელუდოოკოვი ეოტოპიოეი სეი დარეი (40%), ჟელუდოოკოვი სეი დარეი (20%), AV ბლოკი I სტეპენი (30%), ბლოკი II სტეპენი მობიეი I (15%), ულოვი რიშმ (60%). ვი ობოი სლუოეი პარი ჟელუდოოკოვი ეოტოპიოეი სეი დარეი ნოსილი სერევიშნი ხაროქტერი, ი ისსლეოვანი ბოლო სროოი პრეკრიშენი. ვი ჯიკლუოენი სლეოდი ოტმეიტი, კოი უვლენი პოდროოტოკოვ სარშენი ვოიშტიკამ ნირიანიი ი სილშენე ემოციონილნი, ნიოიშნი ვოზბუჟენი სეროენი მოგუი ივლიეილი რიშმ-ფიოტორამი დევილენი არიშიი.

### რეზიუმე

უფროსი ასაკის ჯანმრთელ მოზარდ ვაჟებში ცივ წყალში ჩაყვინთვით გამოწვეულ აპნოეზე გულის რითმის ინდივიდუალური ცვლილებების ვარიაციული ხასიათი

<sup>1</sup>ტომაშ კ. ვირუბა, <sup>2</sup>პაველ მუშალ, <sup>3</sup>ჰანა სვიკალოვსკა

<sup>1</sup>სოციილური დი პუმანიტარული მეცნიერებების ვარშეის სკოლა, ფიზიოთერაპიის დეპარტამენტი, სოპოტი, პოლონეთი;

<sup>2</sup>გდანსკის სამედიცინო უნივერსიტეტი, ფიზიოლოგიის დეპარტამენტი, პოლონეთი

სუნთქვის შეკავება სახის ცივ წყალში ჩაყოფასთან ერთად იწვევს ჩაყვინთვის რეფლექსს, რის შედეგადაც ვითარდება ბრადიკარდია, პერიფერული ვაზოდილატაცია და სისხლის გადანაწილება უპირატესად სასიცოცხლო ორგანოებში. ინდივიდუალური პასუხები ცვალებადი და მეტად გამოხატულია უმცროს ბავშვებში; ინტენსივობა ასაკის მატებასთან ერთად მცირდება. პრაქტიკული მნიშვნელობისაა ჩაყვინთვაზე კარდიალური რეაქციის დეტალური შეფასება უფროსი ასაკის მოზარდებში, რომლებიც განსაკუთრებით მიდრეკილნი არიან მოულოდნელი ჩაყვინთვითი ექსპერიმენტებისადმი, რაც იწვევს ამასთან დაკავშირებულ გართულებებს. კვლევა ჩატარდა, რათა დადგენილ იყო გულის რითმის რეაქცია კონტროლირებად სუნთქვის შეკავებით ცივ წყალში ჩაყვინთვაზე ჯანმრთელ მოზარდებში. 17.5-20.4 წლის ასაკის მოხალისე ასრულებდა შემდეგ პროცედურას - სახის ცივ წყალში ჩაყოფას სუნთქვის მაქსიმალურად

ხანგრძლივი შეკავებით. გულის რითმი განიხილვებოდა უწყვეტი ელექტროგრაფიული ჩანაწერით. ჩაყვინთვის საშუალო დრო ( $t_p$ ) იყო 77.5±10.5 წმ, დიაპაზონი - 61.7-95.4 წმ. აპნოე და სახის ჩაყოფა ცივ წყალში ორფაზიან პასუხს იძლეოდა: გულის რითმის სიხშირის მომატებას მოჰყვებოდა მისი თანდათანობითი შემცირება საბოლოო საზღვრამდე - 47.7±9.0 გულისცემა/წთ ჩაყვინთვის 55.2±16.1 წამზე. გამოიყო გულის რითმის სიხშირის შემცირების ორი პატერნი: ფუნქციის მონოექსპონენციილური შემცირება უკეთესად შეესაბამებოდა 8 (40%) მოზარდს მუდმივი რითმით  $\tau$  - 31.3±11.4 წმ<sup>-1</sup>, მაშინ როდესაც უმრავლესობამ (60%) გამოავლინა ორფაზიანი უარყოფითი ქრონოტროპული ეფექტი მუდმივი რითმით -  $\tau_1$  - 10.3±4.2 წმ<sup>-1</sup> და  $\tau_1$  - 25.5±10.1 წმ<sup>-1</sup>. საწყისი მოსალოდნელი აგზნება ზეგავლენას ახდენდა გულის რითმის სიხშირის ცვლილებაზე: რაც მეტი იყო რითმის თავდაპირველი მატება, მით უფრო ძლიერი იყო



ბრადიკარდიის გამოხატულება. უმრავლესობას გამოუვლინდა გულის რითმის დარღვევები: პარკუჭზედა ექტოპიური დარტყმები (40%), პარკუჭოვანი დარტყმები (20%), I ხარისხის ატრიოვენტრიკულური ბლოკადა (30%), II ხარისხის ბლოკადა - Mobitz I (15%), კვანძოვანი რითმი (60%). ერთ შემთხვევაში რამდენიმე

პარკუჭოვანი ექტოპიური დარტყმა სერიოზულ ხასიათს ატარებდა და კვლევა სასწრაფოდ იქნა შეწყვეტილი. უფროსი ასაკის მოზარდების ლტოლვა ყვინთვისადმი და ემოციებით გამოწვეული გულის აგზნებულობის მაღალი საწყისი დონე მათში არითმიის განვითარების რისკ-ფაქტორს წარმოადგენდა.

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## ВАРИАБЕЛЬНОСТЬ СЕРДЕЧНОГО РИТМА У ЗДОРОВЫХ ПОДРОСТКОВ И МОЛОДЫХ МУЖЧИН

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В последнее время большое внимание уделяется оценке вегетативной нервной системы подростков, как универсальному адаптационному звену в регуляции физиологических и патологических процессов.

Начало болезни определяется как явление адаптационного скачка в функциональных системах, а сама болезнь – как результат истощения адаптационных механизмов. Изменение вегетативного статуса рассматривается в качестве одного из основных донозологических критериев соматического неблагополучия [2].

В ряде случаев нарушение равновесия между симпатическим и парасимпатическим отделами вегетативной нервной системы носит позитивный характер и вызывает мобилизацию компенсаторных механизмов, а в некоторых случаях является негативным процессом, который вызывает развитие заболевания или осложнение уже существующей патологии.

Для оценки симпатической и парасимпатической активности в настоящее время широко используется метод изучения variability сердечного ритма, который имеет высокое диагностическое

значение, поскольку выявляет наличие вегетативного дисбаланса [1,3-5].

Целью исследования явилась сравнительная характеристика variability сердечного ритма у подростков и здоровых молодых мужчин.

**Материал и методы.** В исследовании участвовали 52 подростка мужского пола в возрасте 15-16 лет и 80 молодых мужчин в возрасте 18-22 года. Для достижения легитимности и с целью включения участников в процесс исследования заполнялась анкета, позволяющая комплексно оценить состояние здоровья (пульс, артериальное давление - АД, частота и глубина дыхания ЧД). После анкетирования контингент исследования составили 41 подросток и 73 молодых мужчин. Данное исследование было неклиническим – для объекта оно не имело диагностического, лечебного или профилактического значения, носило добровольный характер и проводилось двойным слепым методом. Участники были информированы о цели и методах исследования. От родителей подростков было получено информированное согласие на проведение данного исследования.

Для оценки variability сердечного ритма согласно общепринятым научно-клиническим стандартам, разработанным западно-европейскими и американскими специалистами, вычислялись следующие статистические параметры: среднее арифметическое (M), среднеарифметическое отклонение (m), стандартное отклонение (SDNN), стандартное отклонение среднего значения RR интервала (SDANN).

Спектральный анализ осуществлялся в диапазоне 0,002-0,5 гц классического распределения Фурье. Биосигнал был разделен на три частотные полосы: а) высокочастотные волны – (HF), отражающие парасимпатическое звено модуляции сердечного ритма; Норма – 15-25%; б) низкочастотные волны (LF), которые считают маркерами симпатической нервной системы (колебание в норме в пределах 15-40%); в) более низкочастотный диапазон (VLF)

в норме колеблется в пределах 15-35%, отражает влияние высших центров вегетативной регуляции на сердечный ритм. Эти расчеты позволяют получить индекс вагосимпатического взаимоотношения LF/HF.

Проводилось комплексное эхокардиографическое исследование. Статистическую обработку полученных данных осуществляли с помощью метода вариационной статистики, используя пакет программ Statistics v. 5,0.

**Результаты и их обсуждение.** Результаты обследования 41 здорового подростка в возрасте 15-16 лет и 73 здоровых молодых мужчин в возрасте 18-22 года выявили, что состояние вагосимпатического равновесия у обследуемых лиц неодинаково, исходя из этого, реципиенты 15-16 лет были разделены на 3 группы (таблица 1).

Таблица 1. Распределение лиц по состоянию вегетативного равновесия

Контингент	I группа сбалансированное вагосимпатическое равновесие	II группа преобладание парасимпатического отдела	III группа преобладание симпатического отдела
подростки 15-16 лет n=41	15 36,6±8%	9 22,0±7%	17 41,5±8%
молодые мужчины 18-22 лет n=73	42 57,5±6%	17 23,3±5%	14 19,2±4%

I группа (n=15) - лица с сбалансированным вагосимпатическим равновесием; II группа (n=9) – с усиленным тонусом парасимпатической части вегетативной нервной системы и III группа (n=17) – с усилением механизмов симпатической регуляции. Таким же образом были разделены молодые мужчины (18-22 лет) I группа - 42,

II - 17, III группа – 14, соответственно. В подростковом периоде в I группе LF/HF был равен 1,8±0,07, во II группе - 1,02±0,09, в III группе - 2,7±0,19. У молодых мужчин I группы индекс вагосимпатического взаимоотношения - LF/HF=1,89±0,08; II группы – 0,93±0,07, III группы - 3,1±0,13 (таблица 2).

Таблица 2. Показатели спектральной плотности сердечного ритма у здоровых лиц в состоянии покоя

Группы		Статистические показатели			
		LF%	HF%	VLF%	LF/HF
подростки 15-16 лет n=41	I	42,4±1,9	26,4±2,06	25,63±3,05	1,8±0,07
	II	31,2±2,7	34,42±1,73	24,92±3,45	1,02±0,09
	III	45,62±2,41	20,46±1,32	32,1±3,5	2,7±0,19
молодые мужчины 18-22 лет n=73	I	48,66±2,82	25,85±1,77	25,4±4,3	1,89±0,08
	II	36,5±3,5	36,6±1,9	22,97±4,2	0,93±0,7
	III	49,2±3,6	15,8±1,35	34,9±3,8	3,1±0,13

Изучение статистических показателей variability сердечного ритма выявило следующую картину:

Таблица 3. Показатели variability сердечного ритма

Группы		M	SDANN	SDNN
подростки 15-16 лет n=41	I гр. n=15	0,68±0,14	98,03±3,5	86,4±7,4
	II гр. n=9	0,72±0,12	92,8±7,1	88,4±4,5
	III гр. n=17	0,74±0,16	96,7±4,9	85,1±3,9
молодые мужчины 18-22 лет n=73	I гр. n=42	0,71±0,12	124±9,1**	91,3±5,3
	II гр. n=17	0,69±0,17	130±8,5***	94,4±9,4
	III гр. n=14	0,73±0,14	128±5,7***	96,1±8,3

достоверность \* $p < 0,05$ , \*\* $p < 0,005$ , \*\*\* $p < 0,001$

Полученные результаты еще раз подтвердили неодинаковое состояние вегетативного равновесия у здоровых лиц, что объясняется различными физиологическими процессами подросткового возраста. Можно предполагать, что подобные стартовые условия могут оказать влияние на характер ответных реакций организма при различных раздражающих воздействиях.

В подростковом возрасте наблюдается превалирование симпатических регуляторных механизмов, тогда как в зрелом возрасте чаще встречаются лица со сбалансированным состоянием вегетативной нервной системы в условиях физиологического покоя при отсутствии патологии.

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#### SUMMARY

#### CHARACTERISTICS OF HEART RATE VARIABILITY IN HEALTHY ADOLESCENTS AND MALE ADULTS

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The primary purpose of the present article is to investigate the comparative characteristics of heart rate variability in healthy adolescents and male adults. The study was carried out on 41 male adolescents aged 15-16 years and 73 male adults aged 18-22 years. For assessment of heart rate variability statistical data of variability and spectral analysis of heart rate were estimated.

Achieved results have proved once again that vegetative balance in healthy individuals is not identical that can be explained by various physiological processes of adolescent age. Such start conditions probably may affect the character of body response to different stimulative impacts.

The study suggests that adults tend to have the prevalence of sympatic regular mechanisms whereas in mature age the cases of individuals with the balanced vegetative nervous system in quiescent mode without pathologies are much more frequent.

**Key words:** heart rate variability, healthy male adolescents and adults.

## РЕЗЮМЕ

### ВАРИАБЕЛЬНОСТЬ СЕРДЕЧНОГО РИТМА У ЗДОРОВЫХ ПОДРОСТКОВ И МОЛОДЫХ МУЖЧИН

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Целью исследования явилась сравнительная характеристика вариабельности сердечного ритма у подростков и здоровых молодых мужчин. Обследованы 41 подросток мужского пола в возрасте 15-16 лет и 73 молодых мужчин в возрасте 18-22 лет. Для оценки вариабельности сердечного ритма вычисляли статистические показатели вариабельности и проводили спектральный анализ ритма.

Полученные результаты подтвердили неодинаковое состояние вегетативного равновесия у здоровых лиц, что объясняется различными физиологическими процессами, происходящими в подростковом возрасте. Можно предполагать, что подобные стартовые условия могут оказать влияние на характер ответных реакций организма при различных раздражающих воздействиях.

В подростковом возрасте наблюдается превалирование симпатических регуляторных механизмов, тогда как в зрелом возрасте чаще встречаются

сбалансированное состояние вегетативной нервной системы в условиях физиологического покоя при отсутствии патологии.

## რეზიუმე

ჯანმრთელ მოზარდთა და ახალგაზრდა მამაკაცთა გულის რიტმის ვარიაბელობის შეფასებითი დასასიათება

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კვლევის მიზანს წარმოადგენდა გულის რიტმის ვარიაბელობის შედარებით თავისებურებების დადგენა ჯანმრთელ მოზარდთა და ახალგაზრდა მამაკაცებს შორის. გამოკვლეულ იქნა 15-16 წლის მამრობითი სქესის 41 მოზარდი და 73 18-22 წლის ახალგაზრდა მამაკაცი. გულის რიტმის ვარიაბელობის შეფასების მიზნით ვანგარიშობლით ვარიაბელობის სტატისტიკურ მაჩვენებლებსა და ვაწარმოებლით რიტმის სპექტრულ ანალიზს.

გამოკვლევებმა დაადასტურა სარეგულაციო მექანიზმების არაერთგვაროვნება ჯანმრთელ პირებში, რაც განპირობებულია მოზარდებში მიმდინარე ასაკობრივი და ფიზიოლოგიური პროცესების თავისებურებებით. სავარაუდოა, რომ არსებული სასტარტო პირობები გავლენას ახდენს ორგანიზმის საპასუხო რეაქციაზე გარეშე გამაღიზიანებლის ზემოქმედების დროს. ფიზიოლოგიური სიმშვიდის დროს ჯანმრთელ მოზარდთა ასაკში ადგილი აქვს სიმპათიკური სარეგულაციო მექანიზმების უპირატესობას, მაშინ როდესაც ზრდასრულ ასაკში, უფრო ხშირად გვხვდება პირები დაბალანსებული ვეგეტატიური სარეგულაციო მექანიზმებით.

## ADVOCATING AN AGENTIC AND POTENTIALIST VIEW TO HEALTH PSYCHOLOGY

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Health psychologists who believe that it is a primary responsibility of individuals' to chart their own way to health should take into particular account the notions of agency and potentials.

These two notions are crucial for reorienting psychological investigations and interventions in accordance with new findings about human personality and the new demands of society. In reality promoting personal welfare requires to focus on what individuals can become beyond what they tend to be like [7], and societies must learn how to capitalize on their citizen's mental capital if they are to prosper and flourish in a rapidly changing world [4].

Whereas the notion of agency points to the fact that people may actively contribute to the full expression of their natural and social endowments, the notion of potentials highlights the fact that much of human strengths derive from people discovering and nurturing their capacities while acknowledging environmental opportunities.

Capacities for self regulation through self reflection, self evaluative reactions and forethought are unique endowments of human species that allow people to adjust cognitive, affective and behavioural responses in order to attain personal goals and thus to exert a considerable influence over their experience and course of life.

People select, interpret and transform the environments they encounter, and to a great extent are responsible for the full expression of their talents, as these develop in interactions with the social context.

Environments contain resources, opportunities, and challenges whose influence is not invariant across people and remains latent in absence of active choice. Even assets and strengths do not impose on individuals but must be actively pursued.

Ultimately people are causal agents who contribute to the full realization of their potentials by the choices they make.

Thus a basic goal of agentic and potentialist views is to shed light on the psychological systems that enable people to regulate their experiences and actions and thus to contribute to the development of their potentials.

In this regard a large body of research attest to the merits of social cognitive theory (SCT) in providing a firm basis for guiding research and designing psychosocial interventions aimed at maximizing individuals' functioning and well being.

SCT, in fact, focuses on the unique properties of human agency that allow people to reflect on their capabilities for action and to accord their conduct to the pursuit of outcomes they value. Moreover SCT points to structures and processes which enable people to guide behaviour purposively and to chart the course of their life.

Among mental structures that attest to the functioning of integrated systems capable of conferring unity, continuity and directness to individuals' action, the beliefs people hold in their capability to exert control over the events that affect their lives (self efficacy beliefs), are pervasively influential.

A vast body of research suggest that self efficacy beliefs are central features of human agency that play a key role in the full realization of individuals' potentials [2].

Unless people believe they can produce desired results by their actions, they have little incentive to undertake activities and seek opportunities they perceive beyond their reach.

People who doubt their efficacy for performance tend to avoid challenges, to withdraw when confronted with difficulties, and to experience debilitating anxiety when faced with setbacks. People who are confident in their efficacy, instead, tend to commit themselves to more challenging goals, to attribute positive outcome to stable and controllable factors and to develop superior strategies for coping with highly complex tasks.



As people draw their sense of efficacy from dealing successfully with challenging experiences SCT points to mastery experiences as effective means for boosting self efficacy.

The degree of perceived mastery varies across task and situations; thus self efficacy beliefs do not correspond to general self appraisal tendencies, but rather to highly contextualized knowledge structures regarding one's own abilities to face specific challenges.

In this vein claiming the specificity of perceived self efficacy and pursuing a multifaceted approach in the study of its various expressions across task, situations and subjective states have been critical to address the self regulatory process and mechanism from which their properties derive.

However self efficacy beliefs do not operate in isolation from one another and may generalize across activities as people reflect on their experiences across various settings. Moreover, people develop interrelated beliefs about capabilities pertaining to broad domains of functioning and beyond specific performances and situations.

Discovering the kinds of self efficacy beliefs that exert a higher influence in given domain of functioning, generalize more widely and are more accessible to change is crucial to account for the unique organization of personality and to design interventions aimed at promoting individual growth, health and well being.

In previous studies I emphasized how self efficacy beliefs related to broad domains of functioning, like affect and interpersonal relations, may have a fundamental role in well being and healthy adjustment [5]. In particular I proposed a conceptual model in which perceived self efficacy in handling affect, including the management of negative and positive emotions, influences perceived efficacy in managing interpersonal and social relations.

In assigning causal primacy to affect over relations management I reasoned that the more effectively people can deal with their own affect, the more they can properly handle their relationships with others, and thus perform successfully in their diverse life contingencies. Likewise the more people believe that they are handling well their emotions, the more justified they are to believe they are capable to adequately handle their relationships with others.

Our earlier studies demonstrate that perceived self efficacy in managing: i) negative affect associated to dependency and irritation; ii) joy and pride; iii) and relationships with others, contrast shyness, depression and delinquency over the course of adolescence and is ultimately fundamental in shaping prosocial behavior [1,3,10].

Subsequent findings with a variety of samples indicated that affective self regulatory beliefs and self efficacy beliefs in managing relationships with others within and outside the family contribute significantly to a latent dimension that underlies life satisfaction, self esteem and optimism, namely positive orientation, a dimension that proved stable over time and due to a large genetic component [8,9,11].

In a previous editorial Taylor [14] pointed to the need to develop interventions that may help people restore their sense of self esteem, optimism and mastery about the future as these are significantly associated with healthy adjustment.

Recent findings suggest that this need can be met, at least in part through mastery experiences conducive to strengthen emotional and social efficacy [6].

Current studies focusing on change of basic traits like the Big Five (that is: extraversion, agreeableness, emotional stability conscientiousness and openness) further attest to the influential role of self efficacy beliefs in shaping basic tendencies that advocates of dispositional approach view as the universal raw material that defines individuals' potential and direction [12,13].

This is particular notable since genetic and longitudinal studies attest to the stability of the big five while a vast literature documents their relations with health, well being, social adjustment and positive functioning. Whereas lack of agreeableness and emotional stability has been associated to various personality disorders, heart diseases, and depression, conscientiousness has been associated to longevity [7].

As we know very little about effectiveness of interventions aimed at promoting the positive sides of personality, current findings on the influence that affective self regulatory and social self efficacy beliefs may exert on stability and change of basic traits look particularly promising.

At any rate, any approach to psychological interventions aimed at building and strengthening individuals' capacities to take care of their health and well being must meet the earlier recommendations of Yardley and Moss [15] who urged the identification of psychological mediators and moderators of intervention outcomes.

Agentic self-beliefs in the domain of affect and interpersonal relations may represent fundamental psychological mediators and moderators, that significantly contribute to turn largely inherited tendencies and predispositions into proper views, feelings, goals and performances.

It is worth noting that genetic endowment accord more with epigenetic probabilism than with mechanistic determinism. Thus positive orientation and basic traits may be thought of as potentials the realization of which largely depends on individual's capacity to master their own experiences.

Social cognitive theory and practice provide unique directions to identify the strategies more suitable to promote individual flourishing by enabling people to make choices and to engage in pursuits that mostly serve to their growth, health and well-being.

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## SUMMARY

### ADVOCATING AN AGENTIC AND POTENTIALIST VIEW TO HEALTH PSYCHOLOGY

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The article covers the notions of agency and potentials, social cognitive theory (SCT), their definition and importance for the health. These two notions are crucial for reorienting psychological investigations and interventions in accordance with new findings about human personality and the new demands of

society. The notion of agency points to the fact that people may actively contribute to the full expression of their natural and social endowments, the notion of potentials highlights the fact that much of human strengths derive from people discovering and nurturing their capacities while acknowledging environmental opportunities. A basic goal of agentic and potentialist views is to shed light on the psychological systems that enable people to regulate their experiences and actions and thus to contribute to the development of their potentials. In this regard a large body of research attest to the merits of social cognitive theory (SCT) in providing a firm basis for guiding research and designing psychosocial interventions aimed at maximizing individuals' functioning and well being. SCT focuses on the unique properties of human agency that allow people to reflect on their capabilities for action and to accord their conduct to the pursuit of outcomes they value, and points to structures and processes which enable people to guide behaviour purposively and to chart the course of their life. Social cognitive theory and practice provide unique directions to identify the strategies more suitable to promote individual flourishing by enabling people to make choices and to engage in pursuits that mostly serve to their growth, health and well-being.

**Key words:** Health psychology, agency, potential, social cognitive theory.

## РЕЗЮМЕ

### ОТСТАИВАЯ ВЗГЛЯД НА ПСИХОЛОГИЮ ЗДОРОВЬЯ КАК ДЕЙСТВИЕ И ПОТЕНЦИАЛ

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В статье анализируются социально когнитивная теория и такие понятия как деятельность и потенциал, даётся их определение; указывается на их значимость в контексте психологии здоровья. Когнитивным процессам, обеспечивающим ментальный самоконтроль и самоэффективность личности, отводится особое место в совместном взаимодействии и взаимовлиянии среды, поведения и личностных факторов. Отмечается основополагающее значение понятий действие и потенциал для переориентации психологических исследований и интервенции (вмешательства) в

соответствии с учётом новых запросов общества и знаний о человеческой личности. Понятие действие указывает на способность людей активно корректировать заложенные в них природные дарования. Понятие потенциал, признавая влияние среды, подчёркивает тот факт, что в большинстве своём человеческая сила развивается у тех людей, которые, смогли открыть и развить заложенные в них способности. Основной целью взгляда на психологию здоровья как действие и потенциал является пролить свет на психологические системы, которые дают возможность людям соразмерять свой опыт и действия и таким образом развивать свои потенциалы. В этой связи в большом числе исследований отмечаются достоинства социально-когнитивной теории в обеспечении твёрдой основы для проведения исследований и разработки психосоциальных интервенций с тем, чтоб максимально повысить функциональное и социально-психологическое благополучие индивидуума. Социально-когнитивная теория сосредотачивается на уникальных свойствах человеческой деятельности, позволяющей людям размышлять над их способностями к действию и согласовывать свое поведение с достижением ценных для них целей, и указывает на структуры и процессы, которые позволяют людям вести себя целеустремленно и картировать течение своей жизни. Социально-когнитивная теория и практика обеспечивают уникальные направления для идентифицирования стратегий, наиболее подходящих для способствования процветания индивидуума, позволяя людям делать выбор и заниматься тем, что главным образом служит их росту, здоровью и хорошему самочувствию.

რეზიუმე

ქმედებისა და პოტენციურობის ცნებები ჯანმრთელობის ფსიქოლოგიაში

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რომის უნივერსიტეტი "Sapienza", იტალია

სტატიაში გაანალიზებულია ქმედებისა და პოტენციურობის ცნებები, სოციალურ-კოგნიტიური თეორია (სკთ) და მათი მნიშვნელობა ჯანმრთელობისათვის. ეს ორი ცნება უკიდურესად მნიშვნელოვანია ფსიქოლოგიური კვლევების რეორიენტაცი-

ისათვის ადამიანის ინდივიდუალობისა და საზოგადოების მოთხოვნების ახალ ინფორმაციასთან შესაბამისობაში მოსაყვანად. ქმედების ცნება მიუთითებს იმ ფაქტზე, რომ ადამიანებს შეუძლიათ აქტიურად შეიტანონ წვლილი საკუთარი ბუნებრივი და სოციალური ნიჭის სრულ რეალიზაციაში. პოტენციურობის ცნება გულისხმობს, რომ ადამიანის ძლიერი თვისებების უმეტესობა მაშინ ვლინდება, როდესაც იგი აღმოაჩენს და განავითარებს საკუთარ უნარებს გარემო პირობების გათვალისწინებით. ქმედებისა და პოტენციურობის თეორიის ძირითადი მიზანია იმ ფსიქოლოგიური სისტემების ასხნა, რომლებიც ადამიანებს საშუალებას აძლევს აკონტროლონ საკუთარი გამოცდილება და მოქმედებები და, ამგვარად, ხელი შეუწყონ საკუთარი პოტენციალის განვითარებას. ამ საკითხებზე ორიენტირებული შრომების დიდი რაოდენობა ადასტურებს სოციალურ-კოგნიტიური თეორიის დადებით გავლენას

იმაზე, რომ სამეცნიერო კვლევები და ფსიქოსოციალური ინტერვენციები მიმართული იყოს ადამიანთა ფუნქციონირებისა და მისი კეთილდღეობის მაქსიმალიზაციაზე. სოციალურ-კოგნიტიური თეორია ფოკუსირებულია ადამიანის ქმედების უნიკალობაზე, რაც საშუალებას აძლევს ადამიანებს გაიაზრონ საკუთარი უნარები ქმედებებთან მიმართებაში, შეათანხმონ ქცევა მათთვის ფასეული მიზნების მიღწევის ამოცანასთან და მიუთითებს იმ პროცესებზე, რომლებსაც საშუალებას აძლევს ადამიანს მიზანდასახულად იმოქმედოს და დაგეგმოს საკუთარი ცხოვრება. სოციალურ-კოგნიტიური თეორია და პრაქტიკა გვაჩვენებს უნიკალურ მიმართულებას იმ სტრატეგიის საიდენტიფიკაციოდ, რომელიც ყველაზე მეტად უწყობს ხელს ინდივიდის სრულყოფილ განვითარებას და აძლევს ადამიანს საშუალებას გააკეთოს არჩევანი, რომელიც საუკეთესო იქნება მისი ზრდისათვის, ჯანმრთელობისა და კეთილდღეობისათვის.

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## ПСИХОФИЗИОЛОГИЧЕСКАЯ СТРУКТУРА ВЕРБАЛЬНОГО И НЕВЕРБАЛЬНОГО ИНТЕЛЛЕКТА ДЕТЕЙ 6-7 ЛЕТ С СИНДРОМОМ ДЕФИЦИТА ВНИМАНИЯ И ГИПЕРАКТИВНОСТИ

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Несмотря на длительную историю исследований когнитивных процессов при синдроме дефицита внимания и гиперактивности (СДВГ), данные об особенностях интеллектуального развития у гиперактивных детей противоречивы. В тоже время доказано, что общими для всех форм СДВГ являются нарушения процессов регуляции деятельности и внимания, тех ведущих (фоновых) компонентов психофизиологической структуры интеллектуальной деятельности, которые в значительной степени определяют сформированность вербального и невербального интеллекта [1] и являются центральным звеном в формировании любой познавательной деятельности [14].

У детей с СДВГ отмечаются нарушения рабочей памяти, внутренней речи, эмоционального контроля, мотивации и уровня бодрствования (arousal), т.е. различных аспектов регуляции деятельности при отсутствии выраженных дефицитов операциональных процессов [14,15].

Результаты некоторых исследований свидетельствуют о том, что существуют особенности развития зрительного и зрительно-пространственного восприятия, речи, памяти и других процессов, связанных с обработкой информации [6,12].



В тоже время имеются данные об отсутствии отличий у детей с СДВГ в возрасте 9-12 лет, обследованных с помощью батареи когнитивных тестов внимания и контрольной группы. Противоречивы и данные об интеллектуальном развитии детей с СДВГ, однако в большинстве работ указывается на отсутствие достоверных различий между детьми с синдромом СДВГ и детьми контрольных групп [14,15]. Отличия выявляются в тех исследованиях, когда синдром СДВГ является сопутствующим диагнозом к другим более серьезным заболеваниям.

Таким образом, изучая детей с СДВГ, исследователи сталкиваются с неоднородностью самого синдрома и с особенностями формирования когнитивных процессов. В этой связи особый интерес представляет проведенный нами сравнительный анализ психофизиологической структуры интеллекта у детей 6-7 лет с СДВГ и контрольной группы (без СДВГ).

**Материал и методы.** Для диагностики уровня интеллектуального развития был использован детский вариант методики Д. Векслера в модификации А.Ю. Панасюка [цит. по 5]. Обследовано 22 ребенка с СДВГ и 25 детей без СДВГ (контрольная группа). Обследование детей проводилось на базе ГОУ №1826 САО г. Москвы.

Тестирование проводилось по 12 субтестам: 6 вербальным (1- 6 субтест) и 6 невербальным (7- 12 субтест).

Вербальные субтесты характеризуют способность ребенка воспринимать и анализировать обращенную к нему речь и отражают развитие тех психических функций, которые обеспечивают выполнение задания.

Невербальные субтесты - это преимущественно задания, требующие пространственных умений и основанные на практически-образном действенном мышлении.

Для анализа психофизиологической структуры интеллекта была использована разработанная нами психофизиологическая структура субтестов теста Д. Векслера (таблица 1) [1,7].

В связи с тем, что выполнение задания каждого субтеста определяется многими факторами: оно

может нарушаться как от недостаточности одного из них, так и при совокупном, комплексном дефиците или несформированности различных функций. Для того чтобы оценить этот фактор, необходимо провести качественный анализ выполнения заданий и сопоставить показатели данного субтеста с показателями субтестов, имеющих сходные с ним компоненты психофизиологической структуры.

Важно отметить что, в процессе выполнения каждого задания анализировались особенности организации деятельности - понимание инструкции, планирование, контроль и коррекция деятельности, что позволило при необходимости провести качественный анализ полученных данных. Именно эти функции страдают у детей с СДВГ.

**Результаты и их обсуждение.** Анализ психофизиологической структуры вербального и невербального компонентов интеллекта у детей с СДВГ и контрольной группы показал, что уровень сформированности психофизиологических функций, определяющих эффективность реализации вербальных и невербальных задач, имеет свои особенности у детей этих групп (рис. 1 (А, Б)).

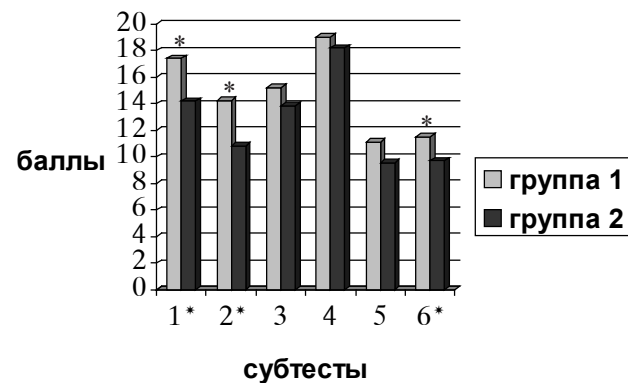


Рис. 1 (А). Средние значения показателей вербального интеллекта у детей 6-7 лет (в баллах)

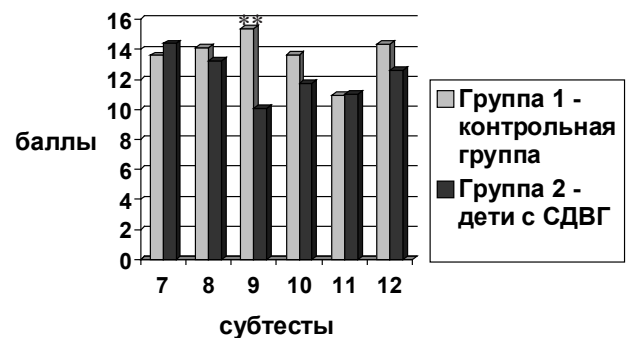


Рис. 1(Б). Средние значения показателей невербального интеллекта у детей 6-7 лет (в баллах)



Таблица 1. Психофизиологическая структура деятельности, составляющая основу субтестов вербального (1-6) и невербального (7-12) интеллекта [1]

Субтесты	Психофизиологическая структура деятельности
1. “Осведомленность”	Произвольная организация и регуляция деятельности. Произвольное внимание (устойчивость, распределение, концентрация). Уровень речевого развития и объем активного и пассивного словаря. Общий запас сведений и знаний. Долговременная слухо-речевая память. Вербально-логическое мышление.
2. “Понятливость”	Произвольная организация и регуляция деятельности. Произвольное внимание (устойчивость, распределение, концентрация). Анализ ситуации. Уровень речевого развития и актуальный словарный запас. Способность к построению развернутого высказывания и умение применять правила. Долговременная слухо-речевая память. Абстрактное и логическое мышление.
3. “Арифметика”	Произвольная организация и регуляция деятельности. Произвольное, активное внимание (устойчивость, распределение, концентрация). Вербально-логическое мышление. Сформированность механизмов вербально-мнестических действий. Сформированность счетных операций, пространственных представлений и зрительно-пространственного восприятия. Регулирующая функция внутренней речи. Слухо-речевая кратковременная, рабочая и зрительная оперативная память. Способность к формированию новых навыков.
4. “Сходство”	Произвольная организация и регуляция деятельности. Произвольное внимание (устойчивость, распределение, концентрация). Уровень речевого развития (состояние активного и пассивного словаря). Запас сведений и знаний. Способность обобщать, анализировать, синтезировать и оперировать понятиями. Вербально-логическое и абстрактное мышление. Слухо-речевая долговременная память.
5. “Словарь”	Произвольная организация и регуляция деятельности. Произвольное внимание (устойчивость, распределение, концентрация). Вербально-логическое и абстрактное мышление, уровень речевого развития и умение строить развернутое высказывание, состояние активного и пассивного словаря. Долговременная слухо-речевая память.
6. “Повторение цифр”	Произвольная организация и регуляция деятельности. Произвольное внимание (устойчивость, распределение, концентрация). Слухо-речевая кратковременная и оперативная память. Уровень сформированности последовательности вербально-мнестических действий.
7. “Недостающие детали”	Произвольная организация и регуляция деятельности. Произвольное зрительное внимание (устойчивость, распределение, концентрация). Запас сведений и знаний. Уровень сформированности регулирующей функции внутренней речи. Пространственное восприятие. Зрительно-пространственная деятельность (умение решать перцептивные задачи).
8. “Последовательные картинки”	Произвольная организация и регуляция деятельности. Произвольное внимание (устойчивость, распределение, концентрация). Наглядно-образное и вербально-логическое мышление. Умение устанавливать причинно-следственные и временные связи. Уровень сформированности регулирующей функции внутренней речи. Актуальный словарный запас. Запас сведений и знаний. Пространственное восприятие.
9. “Кубики Кооса”	Произвольная организация и регуляция деятельности. Произвольное зрительное внимание (устойчивость, распределение, концентрация). Конструктивное мышление. Пространственный анализ и синтез, схематическое представление о пространстве. Зрительно-моторные координации. Способность к формированию новых навыков.
10. “Сложение фигур”	Произвольная организация и регуляция деятельности. Произвольное внимание (устойчивость, распределение, концентрация). Регулирующая функция внутренней речи. Пространственный анализ и синтез. Зрительно-пространственное восприятие. Зрительная память. Зрительно-моторные координации. Способность к формированию новых навыков. Скорость и темп работы.
11. “Кодирование”	Произвольная организация и регуляция деятельности. Произвольное внимание (устойчивость, распределение, концентрация). Зрительно-пространственная деятельность. Зрительная кратковременная память. Способность удерживать в памяти закономерность последовательности символов. Зрительно-моторные координации. Способность к формированию новых навыков. Темп и скорость работы.
12. “Лабиринт”	Произвольная регуляция и организация деятельности. Произвольное внимание (устойчивость, распределение, концентрация). Нервно-мышечная регуляция и контроль движений. Зрительно-моторные координации. Темп и скорость работы.

У детей контрольной группы (рис. 1А) выявлен высокий уровень развития вербально-логического мышления, достаточный запас сведений и знаний, хорошо сформированная долговременная и рабочая память. Об этом свидетельствуют высокие среднегрупповые значения субтестов 1, 2, 3 и 4 («Осведомленность», «Понятливость», «Арифметика» и «Сходство»;  $p=14,25\pm 0,68\div 19,0\pm 0,33$ ), показатели которых находятся выше верхних границ нормативных значений.

Для выполнения субтеста 5 («Словарь») требуется достаточный лексический запас (вербальный объем – тест вербального определения). Успешность выполнения этого субтеста зависит от объема вербальной информации, и в этом отношении субтест 5 («Словарь») перекрывается субтестом 1 («Осведомленность»).

Субтест 6 («Повторение цифр») измеряет объем кратковременной слуховой памяти и частично зрительно-речевой, т.к. цифры имеют, значительно большую, чем слова, наглядную опору.

Показатели выполнения субтестов 5 и 6 («Словарь» и «Повторение цифр»;  $p=11,12\pm 0,46\div 11,50\pm 0,31$ ) несколько ниже, но также находятся в верхних пределах нормативных границ.

В группе детей с СДВГ показатели выполнения четырех вербальных субтестов 1, 2, 3 и 4 («Осведомленность», «Понятливость», «Арифметика» и «Сходство»;  $p=10,80\pm 1,39\div 18,20\pm 0,78$ ) также достаточно высоки, но несколько ниже ( $p>0,05$ ), чем у детей контрольной группы и находятся либо в верхних границах нормативных значений или на верхней нормативной границе. В то же время низкие показатели выполнения вербальных субтестов 5 и 6 («Словарь»,  $p=9,60\pm 0,90$  и «Повторение цифр»,  $p=9,70\pm 0,65$ ) свидетельствуют о недостаточном уровне развития таких структурных компонентов интеллекта как объем актуального словарного запаса и возможности построения развернутого высказывания, кратковременной слухоречевой оперативной памяти и зрительно-речевой памяти. Достоверность различий отмечена только в субтестах 1, 2 и 6 («Осведомленность», «Понятливость» и «Повторение цифр»). Несмотря на низкую степень достоверности ( $p<0,05$ ) различий вербальных субтестов 1, 2 и 6 («Осведомленность», «Понятливость» и «Повторение цифр»),

дети с СДВГ выполняли эти задания с более низким качеством, чем дети контрольной группы.

Выделение наиболее существенных признаков при обобщении и классификации (категории) является главным в субтесте 4 «Сходство» (тест вербального абстрагирования). Высокие показатели выполнения субтеста 4 ( $p=18,20\pm 0,78$ ) скорее свидетельствуют о наученности, так как в основе этого субтеста лежат задания, которые многократно повторяются в течение дошкольного обучения.

Таким образом, качество выполнения вербальных субтестов в контрольной группе выше, чем в группе детей с СДВГ. У детей контрольной группы выявлен высокий уровень сформированности структурных компонентов вербально-логического мышления, речи, внимания и произвольной регуляции деятельности, а дети с СДВГ выполняли эти задания с более низким качеством.

При анализе показателей невербального интеллекта выявлено, что дети обеих групп успешно справлялись с невербальными субтестами (рис. 1Б). В среднем, по группам, результаты выполнения практически всех невербальных субтестов находятся или в верхних границах нормативных значений или даже выше них ( $p=10,07\pm 1,24\div 14,40\pm 0,82$ ). Это свидетельствует о развитии таких важных функций, как наглядно-образное мышление и пространственное восприятие, зрительная память и внимание. В то же время в группе детей с СДВГ субтест 9 («Кубики Кооса»,  $p=10,07\pm 1,24$ ) имеет средний показатель на нижней границе нормативных значений и достоверно ( $p<0,01$ ) отличается от показателей данного субтеста у детей контрольной группы. Это согласуется с результатами некоторых исследований, свидетельствующих о том, что у детей с СДВГ существуют особенности развития зрительного и зрительно-пространственного восприятий [6,12]. В психофизиологической структуре субтеста 9 («Кубики Кооса») ведущую роль играет произвольная организация и регуляция деятельности, схематическое представление о пространстве, операции пространственного анализа и конструктивное мышление (необходимо мысленно расчленив образец на части, соответствующие элементам конструкции, т.е. заранее наметить принцип построения конструкции).

В основе выполнения субтеста 10 (“Сложение фигур”,  $p=11,73\pm 0,86$ ) ведущим является непосредственно зрительно-пространственное восприятие (требуется быстро определить целое и соотношение его частей). Расхождение оценок в субтестах 9 и 10 (“Кубики Кооса” и “Сложение фигур”) может свидетельствовать о преимущественном развитии или недостаточности (несформированности) одного из указанных компонентов зрительно-пространственной деятельности.

В то же время известно, что нарушение обобщенного восприятия пространственных отношений наблюдается при поражении нижнетеменной области левого полушария, а дефицит непосредственного оптико-пространственного восприятия указывает на поражение той же области правого полушария у детей [3]. Поэтому расхождение оценок в субтестах 9 и 10 (“Кубики Кооса” и “Сложение фигур”) может дать основание для предположения о несформированности функций связанных с развитием определенных структур мозга.

Обобщенное представление о пространстве необходимо для формирования понятия числа и одной из сторон импрессивной речи - понимания некоторых логико-грамматических конструкций, которые относятся к функциям левого полушария [3,11]. В связи с этим сочетание низких оценок в субтестах 5, 6 и 9 (“Словарь”,  $p=9,60\pm 0,90$ ; “Повторение цифр”,  $p=9,70\pm 0,65$ ; и “Кубики Кооса”,  $p=10,07\pm 1,24$ ) можно рассматривать как следствие одного радикала – несформированности или дефицита пространственных функций.

Таким образом, анализ выполнения невербальных

заданий свидетельствует о том, что дети двух групп выполняли эти задания успешно, однако у детей с СДВГ выявлены трудности при решении задач, в основе которых лежит зрительно-пространственный фактор.

При анализе интегральных показателей интеллекта проявляются четкие различия между исследуемыми группами детей.

Анализ интегральных показателей интеллекта свидетельствует, что среднегрупповые вербальный (ВИП), невербальный (НИП) и общий интегральные (ОИП) показатели в контрольной группе достоверно ( $p<0,05$ ÷ $p<0,001$ ) выше ( $p=125,43\pm 2,23$ ÷ $130,43\pm 2,23$ ), чем у детей с СДВГ ( $p=114,80\pm 4,10$ ÷ $118,00\pm 4,98$ ).

В связи с тем, что не выявлено существенных различий в выполнении вербальных и невербальных субтестов, а интегральные показатели ВИП и НИП достоверно отличаются, можно предположить, что это обусловлено сохранением операциональной структуры различных видов деятельности, но дефицитом организации внимания и произвольной регуляции деятельности.

Более подробную качественную информацию об особенностях интеллектуального развития дает индивидуальный анализ успешности выполнения заданий теста детьми с СДВГ и детьми контрольной группы.

Динамика качественных показателей выполнения вербальных и невербальных субтестов у детей 6-7 лет с СДВГ и контрольной группы представлены в таблицах 2 и 3.

Таблица 2. Успешность выполнения вербальных субтестов у детей 6-7 лет (%)

Субтесты	Дети 6-7 лет с СДВГ		Дети 6-7 лет контрольная группа	
	Кол-во детей с показ-ми Мах и выше	Кол-во детей с показ-ми Мiн и ниже	Кол-во детей с показ-ми Мах и выше	Кол-во детей с показ-ми Мiн и ниже
1.	73,1±8,7	7,7±5,2	83,8±6,1	7,7±4,4
2.	57,7±9,7	15,4±7,1	70,3±7,5	10,8±5,1
3.	57,7±9,7	15,4±7,1	70,3±7,5	2,7±2,7
4.	96,1±3,8	-	97,3±2,7	-
5.	19,2±7,7	42,3±9,7	16,2±6,1	24,3±7,1
6.	50,0±9,8	15,4±7,1	40,5±8,1	-

Как видно из представленных в таблице 2 данных пять из шести вербальных субтестов (1 «Осведомленность», 2 «Понятливость», 3 «Арифметика»,

4 «Сходство», 6 «Повторение цифр») успешно выполнялись детьми обеих групп. Процент детей, имеющих высокие и очень высокие показатели вы-

полнения субтестов, в основе которых произвольная регуляция деятельности, вербально-логическое мышление и вербально-мнестические операции, а также характеризующих общий запас сведений и знаний и эмоционально-волевою зрелость, колеблется в пределах от 50,0 до 73,1% у детей с СДВГ и от 40,5 до 97,3% у детей контрольной группы.

Для детей с СДВГ субтест 5 («Словарь») оказался наиболее сложным. 42,3% детей с СДВГ имеют минимальные и ниже показатели выполнения. Среди детей контрольной группы процент детей, имеющих трудности выполнения данного субтеста значительно ниже – 24,3%. Успешное выполнение этого субтеста зависит от актуального словарного запаса, умения оперировать вербальной информацией и строить развернутое высказывание. Процентное соотношение высоких результатов выполнения субтеста 5 («Словарь»), т.е. выше верхней границы нормативных значений, не выявил существенных различий в сравниваемых группах и составил 19,2% и 16,2% - соответственно.

Таблица 3. Успешность выполнения невербальных субтестов и интегральных показателей интеллекта у детей 6-7 лет (%)

Субтесты	Дети 6-7 лет с СДВГ		Дети 6-7 лет контрольная группа	
	Кол-во детей с показ-ми Мах и выше	Кол-во детей с показ-ми Min и ниже	Кол-во детей с показ-ми Мах и выше	Кол-во детей с показ-ми Min и ниже
7.	80,8±7,7	3,8±3,7	70,3±7,5	10,8±5,1
8.	76,9±8,3	3,8±3,7	75,7±7,0	-
9.	50,0±9,8	30,8±9,0	70,3±7,5	2,7±2,7
10.	84,6±7,1	7,7±5,2	83,8±6,1	2,7±2,7
11.	46,1±9,8	15,4±7,1	51,3±8,2	18,9±6,4
12.	80,8±7,7	3,8±3,7	91,9±4,5	-
ВИП	42,3±9,7	-	45,9±8,2	-
НИП	61,5±9,5	-	70,3±7,5	-
ОИП	61,5±9,5	-	78,4±6,8	-

Согласно литературным данным [3,13,14], это свидетельствует о развитии таких важных функций, как наглядно-образное мышление и пространственное восприятие, зрительная память и внимание, конструктивное мышление.

От 70,3 до 91,9% учащихся контрольной группы и от 76,9 до 84,6% детей с СДВГ имели показатели выполнения выше верхних нормативных границ.

46,1 и 50,0% детей с СДВГ успешно справились с субтестами 11 и 9 («Кодирование» и «Кубики

Учитывая, что показатели выполнения субтеста 5 («Словарь») характеризуют сложные виды интегративной вербальной деятельности (долговременной памяти, вербально-логического мышления, регулирующей функции речи) трудности реализации заданий этого субтеста свидетельствуют о недостаточном уровне сформированности именно регулирующей функции речи у детей 6-7 лет с СДВГ.

Следует отметить, что согласно результатам анализа индивидуальных данных, самые низкие (на нижней границе нормы или даже ниже) показатели выполнения практически всех вербальных субтестов встречаются у детей с комбинированным типом СДВГ (гиперактивность, невнимательность и импульсивность).

Анализ показателей невербального интеллекта показал, что дети обеих групп справились с невербальными субтестами успешнее, чем с вербальными (таблица 3).

Кооса»), а 30,8% и 15,4% - имели трудности в выполнении.

Средний групповой показатель субтеста 9 («Кубики Кооса») в группе детей с СДВГ также находился на нижней границе нормативных значений и значимо ( $p < 0,01$ ) отличался от показателя этого теста у детей контрольной группы. Это согласуется с нашими данными и результатами некоторых исследований, свидетельствующих о том, что у детей с СДВГ существуют особенности развития зрительно-пространственных восприятий и зрительно-моторных координаций [6,14]. В

психофизиологической структуре субтеста 9 “Кубики Кооса” ведущую роль играет произвольная организация и регуляция деятельности, схематическое представление о пространстве, операции пространственного анализа и конструктивное мышление (необходимо мысленно расчленить образец на части, соответствующие элементам конструкции, т.е. заранее наметить принцип построения конструкции).

Среди ребят контрольной группы 18,9% также испытывали трудности при реализации заданий субтеста 11 («Кодирование»). Успешное выполнение данного субтеста обеспечивается достаточной зрелостью произвольной регуляции деятельности, сложнокординированных движений рук (находятся в стадии формирования) способностью к выработке новых перцептивных навыков (удержание в памяти последовательности символов), т.е. кратковременной зрительной рабочей памятью и зрительно-моторными координациями. Степень сформированности этих функций является фактором, мешающим успешному выполнению данного субтеста детьми двух групп.

Кроме того, желательно отметить, что низкие оценки чаще встречаются у мальчиков. Возможно, это связано с тем, что девочки больше рисуют и охотнее выполняют задания направленные на развитие мелкой моторики.

С субтестом 10 (“Сложение фигур”) успешно справились 84,6 и 83,8% детей 6-7 лет, соответственно.

Результаты выполнения заданий субтеста 10 (“Сложение фигур”) у детей с СДВГ лучше, чем субтеста 9 (“Кубики Кооса”) и находятся на верхней границе нормативных значений. В основе выполнения субтеста 10 (“Сложение фигур”) ведущим является непосредственно зрительно-пространственное восприятие (требуется быстро определить целое и соотношение его частей). Расхождение оценок в субтестах 9 и 10 (“Кубики Кооса” и “Сложение фигур”) по всей вероятности, свидетельствует о преимущественном развитии или недостаточности (несформированности) одного из указанных компонентов зрительно-пространственной деятельности.

Таким образом, у детей с СДВГ выявлены

трудности при решении перцептивных задач, обусловленные как дефицитом зрительно-пространственных функций, так и несформированностью регуляторных компонентов познавательной деятельности.

Сравнение результатов интегральных показателей выявило, что достоверных различий между группами нет и нет детей, чьи результаты были ниже границы нормативных значений. Высокие результаты по ВИП выявлены у 42,3% и 45,9% ребят соответственно. Больше половины детей 6-7 лет имеют показатели НИП и ОИП коэффициентов интеллекта выше верхних нормативных значений - 61,5%, 70,3% и 78,4%.

Индивидуальные варианты структуры интеллекта детей 6-7 лет представлены на рис. 2 (А, Б). Сравнительный анализ индивидуальных вариантов интеллектуального профиля детей с СДВГ и контрольной группы свидетельствуют о вариативности результатов, которые могут быть как очень высокими, так и очень низкими. Из представленного на рис. 2(А) интеллектуального профиля видно, что показатели выполнения и вербальных и невербальных заданий у детей с СДВГ не только выше верхней границы нормативных значений, но и выше показателей детей из контрольной группы.

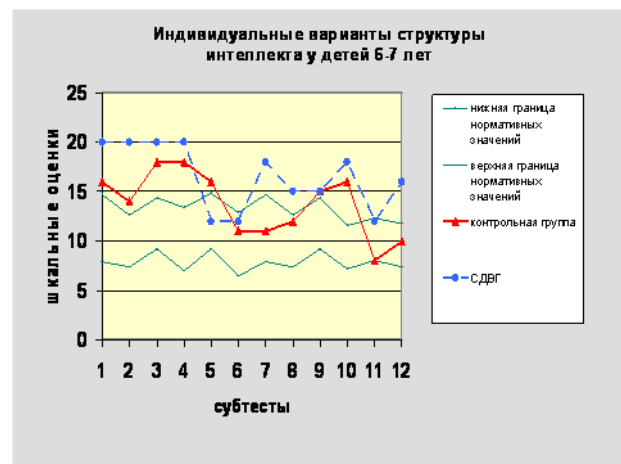


Рис. 2 (А). Показатели индивидуального варианта структуры интеллекта у детей 6-7 лет с СДВГ и контрольной группы

На рис. 2(Б) представлен интеллектуальный профиль с низкими и ниже нижней границы нормативных значений показателями выполнения вербальных и невербальных субтестов. Следует отметить, что интеллектуальный профиль у детей



с низкими показателями результативности выполнения заданий теста носит выраженную дисгармоничную направленность, что характеризует развитие когнитивных функций.

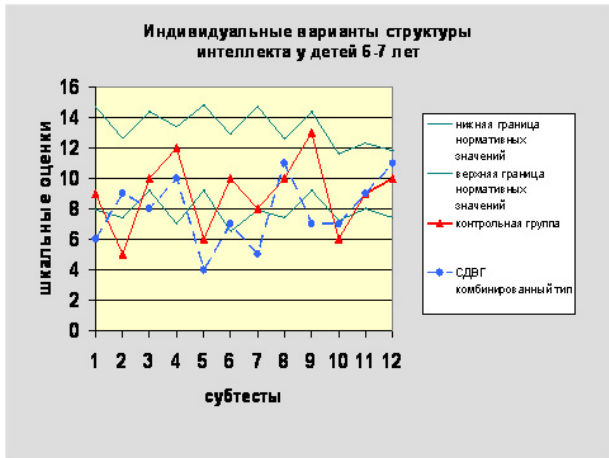


Рис. 2 (Б). Показатели индивидуального варианта структуры интеллекта у детей 6-7 лет с СДВГ и контрольной группы

Корреляционный анализ позволил получить дополнительные данные о внутренней структуре и связи отдельных показателей интеллекта между собой. Анализ коэффициентов корреляции свидетельствует о том, что теснота корреляционных связей по своей структуре и количеству значимых коэффициентов корреляций качественно отличается в исследуемых группах. В контрольной группе корреляционное взаимодействие вербальных и невербальных субтестов по числу образованных, статистически значимых связей почти в два раза выше (70), чем в группе детей с СДВГ (44).

На рисунке 3 (А, Б) представлена структура взаимосвязей внутри вербальных компонентов интеллекта у детей 6-7 лет с признаками СДВГ и у детей контрольной группы.

У детей контрольной группы (рис.3А) наибольшее количество корреляционных связей имеют субтесты 1, 2, 4 и 5 («Осведомленность», «Понятливость», «Сходство» и «Словарь»,  $r = 0,320 \div 0,729$ ). Успешное выполнение заданий этих субтестов, по видимому, зависит от степени сформированности вербально-логического и абстрактного мышлений, долговременной слухо-речевой памяти, уровня речевого развития и способности к построению развернутого высказывания, умения обобщать, анализировать, синтезировать и оперировать понятиями.

У детей с признаками СДВГ (рис. 3Б) фокус связей приходится на субтесты 1, 3 и 6 («Осведомленность», «Арифметика» и «Повторение цифр»,  $r = 0,537 \div 0,864$ ). Общими компонентами психофизиологической структуры этих субтестов являются произвольная организация и регуляция деятельности, долговременная и кратковременная рабочая память, сформированность механизмов вербально-мнестической деятельности, а также зрительно-пространственное восприятие и зрительно-речевая память (объем и умение оперировать вербальной информацией (общий запас сведений и знаний)).

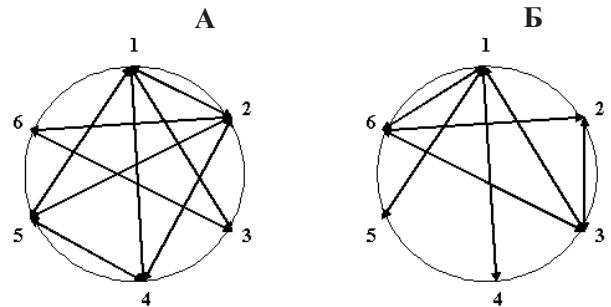


Рис. 3 (А, Б). Взаимодействие внутри вербальной структуры интеллекта у детей 6-7 лет контрольной группы (А) и детей с признаками СДВГ (Б)

Таким образом, как видно из рис. 3 (А и Б) внутри вербальной составляющей интеллекта структура корреляционных связей, а следовательно и возможность поддержания недостаточно сформированных (звеньев) компонентов интеллекта у детей двух групп существенно отличаются по значимости и количеству: у детей контрольной группы на первое место (фокус связей) выходит речевое опосредование психической деятельности (субтесты 1 «Осведомленность», 2 «Понятливость», 4 «Сходство» и 5 «Словарь»), а у детей с СДВГ - зрительно-пространственное восприятие (субтесты 1 «Осведомленность», 3 «Арифметика» и 6 «Повторение цифр») произвольное внимание и произвольная регуляция и организация деятельности, т.к. именно эти компоненты психофизиологической структуры интеллекта обеспечивают их успешное выполнение.

На рисунке 4 (А и Б) представлена структура взаимосвязей внутри невербальных компонентов интеллекта у детей 6-7 лет с признаками СДВГ и детей контрольной группы (без признаков СДВГ).

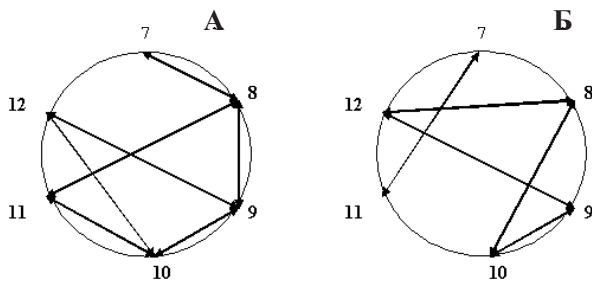


Рис. 4 (А,Б). Взаимодействие внутри невербальной структуры интеллекта у детей 6-7 лет контрольной группы (А) и детей с признаками СДВГ (Б)

Многочисленные литературные источники [1,8,10] и наши многолетние исследования структуры интеллекта свидетельствуют о том, что у детей 6-7 лет невербальный интеллект служит базой для развития интеллекта и имеет менее жесткую структуру (по сравнению с вербальным), содержащую более независимые характеристики [5]. Видимо, это связано с тем, что в онтогенезе невербальные функции активно формируются в дошкольный период и к моменту поступления в школу (6-7 лет) являются наиболее зрелыми [2]. У детей контрольной группы их взаимодействие между собой выше, чем у детей с признаками СДВГ.

У детей 6-7 лет без признаков СДВГ (рис. 4А) фокус связей среди невербальных задач приходится на субтесты 8, 9 и 10 («Последовательные картинки», «Кубики Кооса» и «Сложение фигур»), в психофизиологической структуре которых ведущими являются произвольное (зрительное) внимание и произвольная организация и регуляция деятельности, зрительно-пространственное восприятие и пространственный анализ и синтез, наглядно-образное и вербально-логическое мышление.

В группе детей с признаками СДВГ (рис. 4Б) субтесты 8, 9 и 10 («Последовательные картинки», «Кубики Кооса» и «Сложение фигур») также выступают на первый план.

Таким образом, для успешного решения перцептивных задач необходимы не только сформированное пространственное восприятие, но и психофизиологическая зрелость структурных компонентов организации деятельности и процессов, обеспечивающих произвольность саморегуляции.

На рисунке 5 (А и Б) представлена структура взаимосвязей между вербальными и невербальными компонентами интеллекта у детей 6-7 лет с признаками СДВГ и детей контрольной группы (без признаков СДВГ).

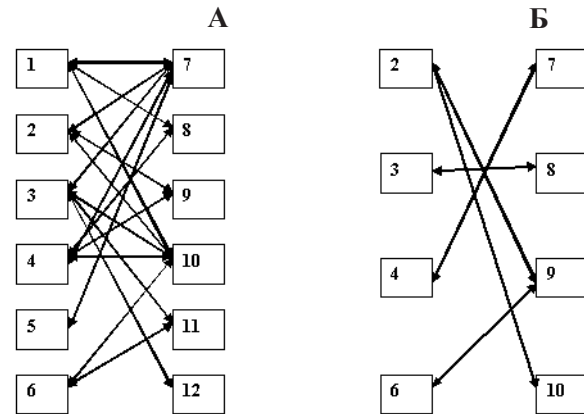


Рис. 5 (А, Б). Взаимодействие между вербальной и невербальной структурами интеллекта у детей 6-7 лет контрольной группы (А) и с признаками СДВГ (Б)

Как видно из рисунка 5 (А), у детей контрольной группы четыре вербальных субтеста – 1, 2, 3 и 4 («Осведомленность», «Понятливость», «Арифметика» и «Сходство») – наиболее тесно коррелируют с невербальными субтестами 7, 8, 9 и 10 («Недостающие детали», «Последовательные картинки», «Кубики Кооса» и «Сложение фигур»), при этом фокус связей приходится на субтесты 3, 4, 7 и 10 («Арифметика», «Сходство», «Недостающие детали» и «Сложение фигур»). Вербальный субтест 5 («Словарь») коррелирует с невербальным субтестом 7 («Недостающие детали»), а субтест 6 («Повторение цифр») с субтестами 10 и 11 («Сложение фигур» и «Кодирование»).

Взаимосвязь этих вербальных и невербальных субтестов определяется общими психофизиологическими компонентами. Развитие импресивной речи, понимание логико-грамматических конструкций и временных отношений, определяют успешное выполнение заданий субтестов 7 и 8 («Недостающие детали» и «Последовательные картинки»), а обобщенное представление о пространстве необходимо для вербально-мнестической деятельности и формирования понятия числа – субтесты 3 и 10 («Арифметика» и «Сложение фигур»). Это дает основания счи-

тать, что успешное решение перцептивных задач также зависит и от регулирующей функции внутренней речи.

Различные структурные компоненты и свойства внимания, входящие в состав и объединяющие субтесты 6, 10 и 11 («Повторение цифр», «Сложение фигур» и «Кодирование»), объясняют их корреляционное взаимодействие.

Можно предположить, что тесное взаимодействие вербальных и невербальных структур интеллекта у детей контрольной группы связано с сформированностью регулирующей функции речи. В то же время, изучение процесса становления регулирующей роли речи показало, что правильное понимание и воспроизведение вербальной инструкции необходимо сопровождать организацией ориентировки в материале (дополнительные опоры), с которым предстоит действовать детям. Речь становится регулятором действия не сама по себе, а только во взаимодействии с практическим действием [1,9].

Данные настоящего исследования согласуются с полученными нами результатами при анализе структуры интеллекта у детей 6-7 лет с разной успешностью обучения.

У детей с признаками СДВГ (рис. 5Б) корреляционное взаимодействие между вербальной и невербальной структурами интеллекта существенно ниже по количеству значимых коэффициентов корреляции и возможности поддержания менее сформированных функций за счет более зрелых.

Таким образом, анализ корреляционного взаимодействия между вербальной и невербальной структурами интеллекта показал, что для детей контрольной группы характерны достаточно высокий уровень сформированности вербально-логического мышления и зрительно-пространственного восприятия, сформированность структурных компонентов организации деятельности и процессов, обеспечивающих произвольность саморегуляции, а для детей с признаками СДВГ - недостаточный уровень сформированности зрительно-пространственного восприятия, произвольного внимания и произвольной организации и регуляции деятельности.

## Выводы

1. Психофизиологическая структура интеллекта детей 6-7 лет с СДВГ, характеризуется выраженной дисгармоничностью развития познавательных функций и низким уровнем взаимосвязи компонентов, составляющих основу вербального и невербального интеллекта, при доминировании невербальной составляющей.

2. Психофизиологическая структура интеллекта детей контрольной группы 6-7 лет характеризуется достаточно высоким для возраста уровнем сформированности познавательных функций и тесным взаимодействием вербального и невербального компонентов.

3. Психофизиологическая структура интеллекта детей 6-7 лет с СДВГ характеризуется недостаточным уровнем сформированности зрительно-пространственного восприятия и произвольной регуляции и организации деятельности и более низким уровнем взаимосвязей вербального и невербального компонентов.

4. Достоверно более низкие ВИП и НИП у детей с СДВГ связаны с дефицитом организации внимания и произвольной регуляции деятельности при сохранности операциональной структуры различных видов познавательной деятельности. Очень низкие показатели выполнения всех вербальных субтестов отмечены у детей с комбинированным типом СДВГ, у которых выявлены гиперактивность, невнимательность и импульсивность.

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## SUMMARY

### PSYCHOPHYSIOLOGICAL STRUCTURE OF VERBAL AND NONVERBAL INTELLECT IN 6-7 YEAR OLD CHILDREN WITH ATTENTION-DEFICIT HYPERACTIVITY DISORDER

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Wechsler test revealed the peculiarities of intellectual development of children with Attention-Deficit Hyperactivity Disorder (ADHD). It is shown that the psychophysiological structure of intelligence in 6-7 year old children without any signs of ADHD

is characterized by a high level of development and close interaction between verbal and nonverbal components. Their peers with ADHD demonstrate an insufficient level of development of visual-spatial perception, voluntary activity organization and regulation, and a lower level of interaction between verbal and nonverbal components. Significant differences between verbal and nonverbal integral indices are the evidence of the deficit in voluntary attention and voluntary regulation and in the integrity of operational cognitive structures.

**Key words:** Attention-Deficit Hyperactivity Disorder, psychophysiology, intellect, ADHD children.

## РЕЗЮМЕ

### ПСИХОФИЗИОЛОГИЧЕСКАЯ СТРУКТУРА ВЕРБАЛЬНОГО И НЕВЕРБАЛЬНОГО ИНТЕЛЛЕКТА ДЕТЕЙ 6-7 ЛЕТ С СИНДРОМОМ ДЕФИЦИТА ВНИМАНИЯ И ГИПЕРАКТИВНОСТИ

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Для выявления особенностей интеллектуального развития у детей с признаками синдрома дефицита внимания и гиперактивности (СДВГ) и детей контрольной группы был использован тест Векслера. Показано, что психофизиологическая структура интеллекта детей контрольной группы 6-7 лет характеризуется высоким уровнем сформированности и тесным взаимодействием вербального и невербального компонентов. Психофизиологическая структура интеллекта детей 6-7 лет с СДВГ, по сравнению с контрольной группой, характеризуется недостаточным уровнем сформированности зрительно-пространственного восприятия и произвольной организации и регуляции деятельности и более низким уровнем взаимосвязей вербального и невербального компонентов. Значимые различия, между интегральными вербальными и невербальными интегральными показателями также свидетельствуют о дефиците произвольного внимания и произвольной регуляции деятельности и сохранности операциональной структуры разных видов познавательной деятельности.



## რეზიუმე

ყურადღების დეფიციტისა და ჰიპერაქტივობის მქონე 6-7 წლის ბავშვების ვერბალური და არავერბალური ინტელექტის ფსიქოფიზიოლოგიური სტრუქტურა

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ყურადღების დეფიციტისა და ჰიპერაქტივობის ნიშნების მქონე 6-7 წლის ბავშვებსა და საკონტროლო ჯგუფში ინტელექტუალური განვითარების თავისებურებების დასადგენად გამოყენებული იქნა ვექსლერის ტესტი. ნაჩვენებია, რომ საკონტროლო ჯგუფის 6-7 წლის ბავშვებში ინტელექტის ფსიქო-ფიზიოლოგი-

ური სტრუქტურა ხასიათდება ვერბალური და არავერბალური კომპონენტების ჩამოყალიბებისა და ურთიერთქმედების მაღალი დონით. 6-7 წლის ბავშვებში ყურადღების დეფიციტითა და ჰიპერაქტივობით, საკონტროლო ჯგუფთან შედარებით, ინტელექტის ფსიქოფიზიოლოგიური სტრუქტურა ხასიათდება მხედველობითი სივრცითი და საქმიანობის ნებელობითი ორგანიზაციისა და რეგულაციის არასაკმარისი ჩამოყალიბებით. ასევე აღინიშნება ვერბალური და არავერბალური კომპონენტების ურთიერთკავშირების უფრო დაბალი დონე. ვერბალურ და არავერბალურ ინტელექტუალურ მაჩვენებლებს შორის არსებითი ცვლილებები მოწმობს ნებელობითი ყურადღების, აქტივობის რეგულაციისა და სხვადასხვა სახის შემეცნებითი საქმიანობის ოპერაციული შენახულობის დეფიციტზე.

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## БИОХИМИЧЕСКИЕ ИЗМЕНЕНИЯ КРОВИ ПРИ РАННЕЙ МАТЕРИНСКОЙ ДЕПРИВАЦИИ У ДЕТЕЙ И ИХ ВЛИЯНИЕ НА СТАНОВЛЕНИЕ ЭМОЦИОНАЛЬНОГО СТАТУСА РЕБЕНКА

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Установлено, что недостаток материнской ласки, редкое общение с матерью с раннего возраста является одним из глубоких стрессовых воздействии на психику ребенка и чаще всего вызывает состояние психической депривации [4]. По данным Amy F.T. Arnsten [7] стрессогенное воздействие на ребенка в раннем возрасте вызывает изменения архитектоники и структуры кортикальной части мозга. Nim Tottenham, Todd A. Hare, Brian T. Quinn, et al. [15] установили нейробиологические и поведенческие нарушения у детей страдающих материнской депривацией. Aniko Korosi & Tallie Z. Baram [6]

выявили, что материнская депривация с раннего детства ведет к становлению неустойчивой психики, формированию неправильного ответа на стрессовые воздействия, проявляясь и во взрослом возрасте. Имеются литературные данные об изменениях содержания нейротрансмитеров и кортизола в крови детей с материнской депривацией [9,10,12]. Ранняя материнская депривация вызывает нарушение адаптационных возможностей нервной деятельности и стратегии поведения, проявляясь в неадекватном поведении и снижении умственных возможностей при созревании организма [4].



Нами установлена [2,5] дискоординация дофаминергической и симпатoadреналовой систем при непрерывной и прерывистой материнской сепарации у маленьких крысят, что проявляется в нарушениях поведенческих реакций во всех возрастных диапазонах. В литературе имеются данные об изменениях содержания серотонина в структурах мозга у животных с материнской депривацией, что проявляется в агрессии, склонности к алкоголю [12]. Опубликованы данные о влиянии ранней материнской депривации на структурные изменения и деградирующие процессы в головном мозге среди животных [14,15].

В настоящем исследовании была поставлена цель определить влияние ранней материнской депривации на становление симпатoadреналовой и дофаминергической регуляции мозга среди детей раннего возраста и последующие эмоциональные проявления в дошкольном возрасте.

**Материал и методы.** Исследования проведены в Доме младенца г. Тбилиси. Основную группу составили 42 клинически здоровых детей в возрасте от 6 до 36 месяцев. В контрольную группу вошли здоровые дети той же возрастной группы от нескольких специализированных приютов г. Тбилиси, где жили матери-одиночки со своими детьми, т.е. дети с рождения росли со своими матерями. Протокол исследования был утвержден локальным этическим комитетом.

Исследовались состояние здоровья детей, их развитие, наличие какой-либо врожденной патологии, острых инфекционных заболеваний в период исследования, тип вскармливания (в контрольную группу вошли дети, которые находились на искусственном вскармливании). В крови избранной когорты здоровых детей исследовались содержание норэпинефрина, дофамина и серотонина. Исследования проведены в Республиканском научно-исследовательском центре медицинской биофизики и внедрения новых биомедицинских технологий им. Н.В. Карсанова. При обработке результатов использовали программу “STAT Soft”, достоверность различий – при  $p < 0,05$ .

Для выявления эмоционального статуса детей использовали 8-цветовой «Малый Тест» Люшера [3]. В основе разработанной Люшером методики лежит теория так называемой функциональной

психологии, основой которой является гипотеза о различной психологической значимости для поведения человека ряда цветов. Работа с тестом заключается в последовательной раскладке исследуемым лицом всего набора восьмицветовых карточек. Следовательно, на один конец ряда попадает наиболее предпочитаемый цвет, а на противоположный конец – наименее предпочитаемый. Интерпретация цветовых раскладок базируется на том, что каждый цвет, как известно, имеет свою психологическую структуру и является признаком определенных поведенческих характеристик человека. Другой основой для интерпретации цветовых раскладок служит место (позиция) цвета в раскладке, которое характеризует отношение человека к тому или иному цвету (функция цвета). Этот параметр позволяет определить личностные характеристики человека – манеру поведения, эмоциональную или мотивационную цель поведения и т.д. Автор теста все цвета разделяет на основные (темно-синий, зеленый, красный, желтый) и вспомогательные (пурпурный или фиолетовый, коричневый, черный, серый). Для здорового нормально развитого индивида характерно, что на первых местах обычно стоят основные цвета. В том случае, если на одной из трех первых позиций находится какой-либо вспомогательный цвет, можно судить о состоянии напряженности, тревожности в самочувствии человека. По методике Люшера в зависимости от позиции дополнительного или основного цвета присваивается балл в 12-бальной шкале. От 0 баллов – отсутствие или незначительная тревожность до 12 баллов – очень высокая тревожность.

Цветовой тест проводили в Цхнетском Доме ребенка среди здоровых детей в возрасте от 4 до 6 лет, которые в возрасте 3 лет были переправлены из Тбилисского Дома младенца. Контрольную группу составили здоровые дети того же возраста из детских садов г. Тбилиси. Разрешение на проведение исследования было получено от Министерства образования Грузии.

**Результаты и их обсуждение.** В крови депривированных детей выявлено достоверно низкое содержание серотонина во всех возрастных диапазонах. Самое значимое различие обнаружено в возрасте до года, когда содержание серотонина было самое высокое в контрольной группе ( $265,2 \pm 26,2$  нмоль/л), но держалось на довольно низком уровне у депривированных детей

(152,2±2,9 нмоль/л). С 1 до 2 летнего возраста концентрация серотонина несколько снижалась в обеих исследуемых группах, а с 2 летнего возраста отмечалась тенденция его повышения, хотя концентрация оставалась достоверно низкой в группе депривированных детей (диаграмма 1).

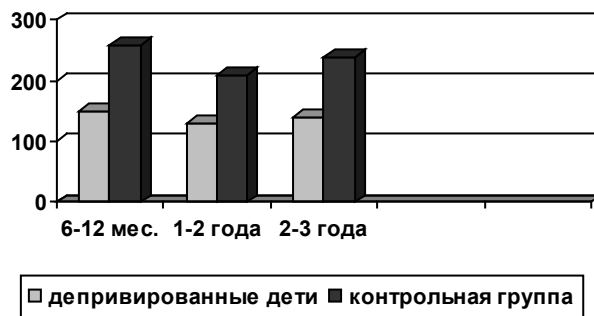


Диаграмма 1. Содержание серотонина (нмоль/л) в крови детей с материнской депривацией

С другой стороны, содержание норэпинефрина было достоверно высоким у депривированных детей по сравнению с контрольной группой во всех возрастных диапазонах, особенно в возрастной группе от 1 до 2 лет (2,07±0,8 мкг/л, по сравнению с контрольной группой – 1,27±0,1 мкг/л). Содержание же дофамина было достоверно низким в первой возрастной группе по сравнению с контролем. С возрастом детей содержание дофамина снижалось как в основных, так и в контрольных группах, но более интенсивное снижение концентрации дофамина отмечалось в крови детей контрольной группы (диаграмма 2).

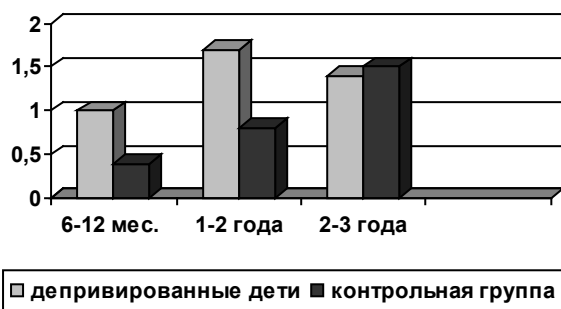


Диаграмма 2. Содержание норэпинефрина (мкг/л) и дофамина (мкг/л) и их соотношение (норэпинефрин/дофамин) в крови депривированных детей

Такой же дисбаланс между содержанием норэпинефрина и дофамина мы отметили в эксперименте с депривированными крысятами [2,5], что указывает на процессы дисрегуляции и функциональных

расстройств в гипоталамо-гипофизарной системе при материнской депривации как среди животных, так и среди людей. Как мы установили и на что указывает множество экспериментальных данных [7,8,12], в основе наблюдаемых в условиях материнской депривации поведенческих нарушений крысят лежит дискоординация дофаминергической и симпатoadреналовой систем.

Для определения психического состояния детей, мотивации поведения, основы поведенческих нарушений был проведен «Малый восьмицветовый Тест Люшера». В результате цветового теста 20,5% детей из детдома выявили высокую тревожность, 10,8% очень высокую тревожность, а у 38% депривированных детей был выявлен низкий уровень тревожности. В контрольной же группе очень высокую тревожность определили у 3% детей, высокую тревожность – у 20,6% детей, а у 59% была выявлена очень низкая тревожность, или вообще не было признаков тревожности.

Общеизвестно о роли серотонина в поведении. Это биологически активное вещество ответственно за расслабление, покой, положительные эмоции. При депрессивном расстройстве отмечается дефицит этого вещества. В психосоматической сфере имеет значение дисбаланс между норадренергической и серотонинергической системами [1]. По данным Currier and Mann [6], Ichise et al. [11] при ранних стрессовых воздействиях слабеет серотонинергическая функция мозга, связывающая потенциал серотонинергических рецепторов мозга [13], что способствует возникновению психопатологического состояния и проявлению агрессивного и суицидального поведения уже в поздние возрастные периоды.

Норадреналин выполняет активирующую функцию в головном мозге. При активации норадреналинергической функции мозга улучшаются внимание, концентрация и состояние бодрствования. Отмечается так же косвенное влияние на эмоционально и мотивационно детерминированное поведение.

Дофамин регулирует целенаправленное поведение. Эффективность антидепрессантов сопровождается повышенной дофаминергической активностью. Доказано, что активация дофаминергической и норадреналинергической систем формирует эмоционально положительные состояния [6].

Результаты нашего исследования выявили дисбаланс между функционированием норэпинефринергической и дофаминергической систем мозга у депривированных детей. Высокая концентрация норэпинефрина, несоответственно низкий уровень дофамина и низкое содержание серотонина в крови детей из детского дома указывают на регуляционные и функциональные нарушения гипоталамо-гипофизарной системы мозга.

Выявленные нами нарушения эмоционального статуса детей из детдома (высокий процент детей с высоким уровнем тревожности) по сравнению с детьми растущими в семейной обстановке являются следствием функциональных нарушений центральной нервной системы с раннего возраста, когда еще не закончено и продолжается ее формирование.

Эмоциональность и преобладание положительных эмоций - характерная черта для нормального ребенка. Эмоциональность помогает ребенку адаптироваться в окружающей среде. В этом ему помогает мать и близкие ему люди. Недостаток таких контактов с раннего детства способствует возникновению психоэмоциональной депривации, что со своей стороны влияет на нормальное формирование нейроэндокринной регуляции еще несформированных структур центральной нервной системы. В дальнейшем формируется поведенческий тип депривированного ребенка, который отличается от поведения ребенка из семьи. Этому способствует окружающая среда, где растет ребенок и чем дольше ребенок будет жить в учреждениях (детские дома, приюты), тем глубже будут нарушения (психосоциальные) и тем тяжелее будут последствия как для самого ребенка, так и для общества [7,10,12,15].

В заключение можно отметить, что ранняя материнская депривация вызывает глубокие нейроэндокринные регуляторные нарушения в гипоталамо-гипофизарной системе, что влияет на эмоциональное состояние и поведение ребенка в поздние возрастные периоды. Чем дольше ребенок страдает от недостатка эмоциональных стимулов, от психической (материнской) депривации, тем глубже психические нарушения, что выражается в психопатологическом поведении (агрессивность, суицид, депрессия).

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## SUMMARY

### BLOOD BIOCHEMICAL CHANGES IN MATERNALLY DEPRIVED CHILDREN AND THEIR EMOTIONAL STATUS

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Environmental rearing conditions during the neonatal period are critical for the establishment of neurobiological factors controlling behavior and stress responsiveness. Early maternal deprivation in animals consisting of a single 24-h maternal deprivation episode during early neonatal life has been proposed as an animal model for certain psychopathologies including anxiety, depression and schizophrenic-related disorders. The aim of the present research was to show the mechanisms how the early maternal deprivation in humans influences the emotional status of children. To understand the effects of early deprivation on the regulation of the hypothalamic-pituitary-adrenal axis of children following social interactions, we examined the blood neurotransmitters levels (Norepinefrin NA; Dofamin DF; Serotonin SE) in a group of healthy institutionalized children at age from 6 to 36 months from Tbilisi Infant's House. A group of healthy children of the same age from Mother & child shelters formed the control group. Emotional status was assessed by Leusher's Color Test in a group of healthy institutionalized children at age from 3 to 6 years from Tskneti Orphanage.

Institutionalized children showed elevations in blood NE and decreased SE and DF concentrations in comparison with non deprived children's blood. The higher was percentage of children with high level of anxiety in the group of children from orphanage than in the children with family care.

The results suggest that early maternal deprivation may contribute to long-term regulatory problems of the stress-responsive system that may be resulted in altered emotionality and behavior in deprived children.

**Key words:** maternal deprivation syndrome, emotional status of children, stress-responsive system, hypothalamic-pituitary-adrenal axis, blood neurotransmitters.

## РЕЗЮМЕ

### БИОХИМИЧЕСКИЕ ИЗМЕНЕНИЯ КРОВИ ПРИ РАННЕЙ МАТЕРИНСКОЙ ДЕПРИВАЦИИ У ДЕТЕЙ И ИХ ВЛИЯНИЕ НА СТАНОВЛЕНИЕ ЭМОЦИОНАЛЬНОГО СТАТУСА РЕБЕНКА

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Цель работы - исследование влияния ранней материнской депривации на становление симпатoadренальной и дофаминергической регуляции мозга детей раннего возраста и последующие эмоциональные проявления.

Исследования проведены в Доме младенца г.Тбилиси на 42 клинически здоровых детях в возрасте от 6 до 36 месяцев. В крови избранной когорты здоровых депривированных детей исследовались содержание норэпинефрина, дофамина и серотонина. Для выявления эмоционального статуса детей использовали восьмицветовой «Малый Тест» Люшера.

В крови депривированных детей выявлено достоверно низкое содержание серотонина во всех возрастных диапазонах. Содержание норэпинефрина было достоверно высоким, а концентрация дофамина достоверно низкой в первой возрастной группе депривированных детей по сравнению с контролем. С возрастом содержание дофамина в крови снижалось, несмотря на высокий уровень норэпинефрина. В результате цветового теста у 20,5% детей из детдома выявлена высокая тревожность, у 10,8% - очень высокая тревожность.



Таким образом, ранняя материнская депривация вызывает глубокие нейроэндокринные регуляторные нарушения в гипоталамо-гипофизарной системе, что влияет на эмоциональное состояние и поведение детей в поздние возрастные периоды.

### რეზიუმე

სისხლის ბიოქიმიური ცვლილებები დედის მზრუნველობის ადრეული დეფიციტის პირობებში და მათი გავლენა ბავშვის ემოციური სტატუსის ჩამოყალიბებაში

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თბილისის სახელმწიფო სამედიცინო უნივერსიტეტი, პედიატრიის დეპარტამენტი, საქართველო

შრომის მიზანს წარმოადგენდა ბავშვის ჰიპოთალამო-ჰიპოფიზური სისტემის რეგულაციური ფუნქციის ფორმირებაზე დედის დეფიციტის გავლენის შესწავლა ადრეულ ასაკში და ბავშვების მოგვიანებითი ემოციური გამოვლინებები.

კვლევა ჩატარებულ იქნა თბილისის ჩვილ ბავშვთა სახლის ბაზაზე 3-6 თვემდე ასაკის ჯანმრთელ ბავშვებში, რომლებიც დაბადებიდან ჩაბარებული იყვნენ ბავშვთა სახლში. საკონტროლო ჯგუფი შეადგინა იგივე ასაკის ჯანმრთელმა ბავშვებმა დედათა და ჩვილთა

თავშესაფრებიდან, სადაც ბავშვები ცხოვრობდნენ დედებთან ერთად. მათ სისხლში გამოკვლეულ იქნა ნორეპინეფრინის, სეროტონინისა და დოფამინის კონცენტრაცია. ადრეული ასაკის დეპრივირებული ბავშვების ემოციური სტატუსი შეფასებულ იქნა ლუშერის ფერადი ტესტით წყნეთის ბავშვთა სახლის 3-6 წლამდე ასაკის აღსაზრდელებს შორის. საკონტროლო ჯგუფი შეადგინა თბილისის სხვადასხვა ბავშვთა ბაზის იგივე ასაკობრივი ჯგუფის აღსაზრდელებმა.

ჩატარებული კვლევის შედეგად გამოვლინდა ნორეპინეფრინის სარწმუნოდ მაღალი მაჩვენებელი დეპრივირებული ბავშვების სისხლში კონტროლთან შედარებით, მაშინ როდესაც დოფამინის კონცენტრაცია სარწმუნოდ დაბალი იყო და ასაკის მატებასთან ერთად განაგრძობდა კლებას. სეროტონინის მაჩვენებელი დეპრივირებული ბავშვების ყველა ასაკობრივ ჯგუფში სარწმუნოდ დაბალი იყო კონტროლთან შედარებით. შესაბამისად, დეპრივირებული ბავშვების 20,5% აღენიშნა მაღალი, ხოლო 10,8% - ძალიან მაღალი შფოთვა.

ამგვარად, ადრეული ასაკიდან დედის დეფიციტი იწვევს ღრმა ნეიროენდოკრინულ რეგულაციურ დარღვევებს ბავშვის ტვინის ჰიპოთალამო-ჰიპოფიზურ სისტემაში, რაც მათი ემოციური სტატუსის შეცვლით ვლინდება.



## DIAGNOSTICS AND MANAGEMENT OF SLEEP-RELATED RESPIRATORY DISTURBANCES IN CHILDREN WITH SKELETAL DYSPLASIA CAUSED BY FGFR3 MUTATIONS (ACHONDROPLASIA AND HYPOCHONDROPLASIA)

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Skeletal dysplasias caused by mutations in the fibroblast growth factor receptor 3-gene (FGFR3) include hypochondroplasia, the heterozygous and homozygous form of achondroplasia, and thanatophoric dysplasia type I and II [7]. With an incidence of 1:25.000 – 1.5:10.000/births, achondroplasia is the most common form of disproportionate dwarfism characterised by osteochondrodysplasia by disturbed endochondral ossification. The pattern of inheritance is autosomal dominant [24].

In 1994, a specific mutation in the fibroblast growth factor receptor 3-gene was identified as the cause for achondroplasia [7]. Furthermore, several FGFR3 mutations have been detected in patients with hypochondroplasia and thanatophoric dysplasia type I, whereas only one mutation has been shown to cause thanatophoric dysplasia type II [7].

In comparison to the general population, children with skeletal dysplasias caused by FGFR3 mutations represent a subpopulation with an increased prevalence of sleep-related respiratory disturbances (SRD) [3-5,8,10,12,13,16-18,21,24] and with an increased mortality rate [6,12,20].

We report our experiences with these patients concerning polysomnographic evaluation and management of SRD.

**Material and methods.** From January 1990 to January 2009, we performed a semi-structured interview, a clinical examination, and a polysomnographic sleep recording (PSG) in 24 patients with skeletal dysplasias caused by FGFR3 mutations (22 achondroplasia, 2 hypochondroplasia; 13 boys, 11 girls; age 8 days to 15 years, median age 3.0 years). We performed 65 polysomnographic sleep recordings in 24 patients including follow-up PSG in 9/24 patients. Informed consent was obtained from all parents. All patients underwent overnight 12-channel polysomnography recording, an electro-encephalogram (2 channels), an electrooculogram (2 channels), a submental electro-

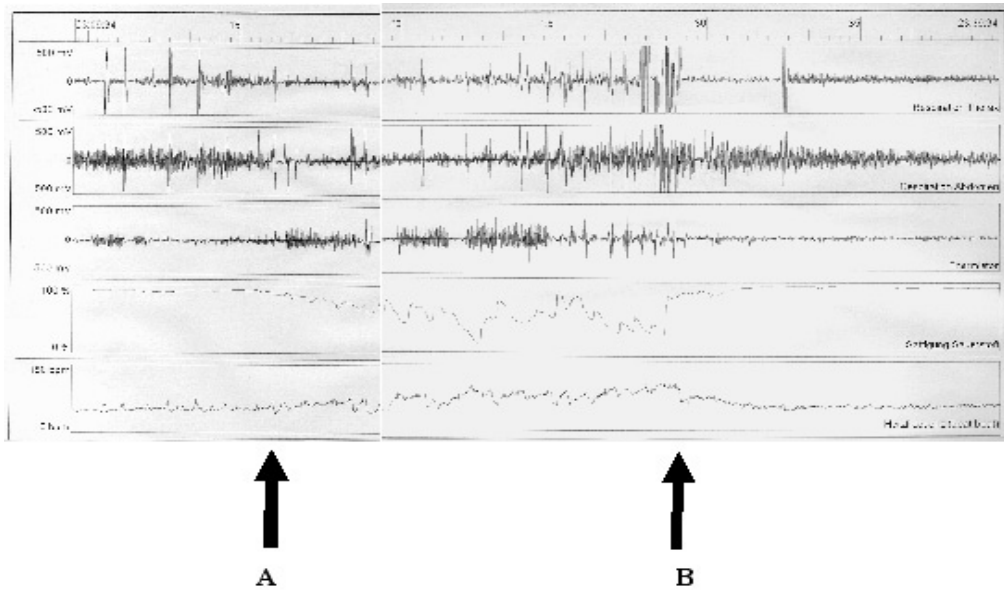
myogram, an electrocardiogram, chest wall motion, abdominal wall motion, nasal-oral airflow, arterial oxygen saturation by pulse oximetry, transcutaneous pO<sub>2</sub>, transcutaneous pCO<sub>2</sub>, and a video recording. All signals were recorded simultaneously and stored using the BRAINLAB 4 polysomnography system (DiaMedic-Schwarzer, Unna, Germany). The polysomnographic recording techniques and the reference values for the different age groups have been described in detail elsewhere [9,15,22]. Data were presented as median and interquartile range. The polysomnographic data of the children with achondroplasia were compared to the data of children, who had undergone PSG before and after adenotonsillectomy (ATE) [14]. In a subgroup of patients with achondroplasia PSG was performed before and after ENT-surgery enabling us to compare these data. As polysomnographic parameters are not normally distributed, statistically significant differences were tested by the Whitney-Mann-U-Test.

### Results and their discussion. Case reports

Case report 1. The 12.8 year old boy, the youngest of eight children of a sinti family, was admitted to our hospital in a life-threatening condition. He had been suffering from daytime somnolence, attention and concentration problems, and morning headaches for several months. The parents had noticed snoring, mouth breathing, labored breathing, and excessive sweating while sleeping. Lately, he had only been able to sleep in the sitting position or in the knee-elbow position. Furthermore, repeated cyanotic attacks while sleeping and apneas had been observed. The boy was obese (weight 52.4 kg; length 112 cm). The ECG showed signs of right ventricular hypertrophy and repolarization disturbances. The echocardiogram showed concentric hypertrophy of the myocardium and signs of pulmonary hypertension. Due to severe respiratory acidosis, the boy was intubated and mechanically ventilated. After undergoing adenoidectomy (AT), a severe obstructive sleep apnea syndrome (OSAS) was still

evident in PSG (Fig. 1). Nasal bilevel positive airway pressure (BiPAP) therapy (pressure: inspiratory 12 hPa; expiratory 8 hPa; bilevel positive airway pressure) led to normalisation of the respiratory

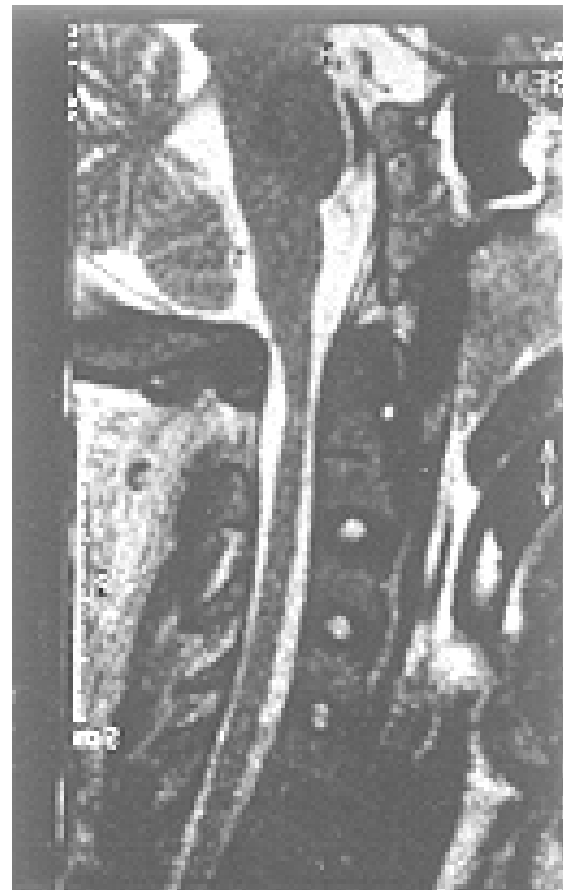
situation during sleep. Cranial magnetic resonance imaging revealed pathologic findings in the area of the brain stem (Fig. 2) and the cervical spinal cord (Fig. 3).



*Fig. 1. Episode of 30 minutes duration from a polysomnographic sleep recording of a 12.8-year-old achondroplastic boy (case report 1). At the time point A the NCPAP-therapy was discontinued for 14 minutes duration. This resulted in marked oxygen desaturation and hypercapnia (not shown in the figure) as well as an increase of heart rate as a consequence of obstructive sleep apneas. At the time point B NCPAP therapy was continued. At once, respiration, blood gases and heart rate were in the normal range*



*Fig. 2. Cranial magnetic resonance imaging of a 12.8-year-old achondroplastic boy (case report 1) with compression of the brain stem. The measure of the Welcker angle (nasion – tuberculum sellae – basion angle) is 120° (normal value 135°) [2]*



*Fig. 3. Detail of the magnetic resonance imaging (case report 1) showing marked thinning and fibrosis of the cervical medulla*

Case report 2

The patient (female) was treated in our institution for 8.6 years (table 1). A decompression operation at the age of 9 months, a liquor drainage at the age of 9 months, and an ATE at the age of 3.2 years had not

been successful in treating OSAS. Therefore, nasal continuous positive airway pressure (CPAP) therapy (pressure: 5 to 8 hPa; continuous positive airway pressure) was performed for 7.8 years. At the age of 11.7 years, we discontinued nasal CPAP therapy (table 1).

Table 1. Long-term observation of a patient with achondroplasia

Age (years)	Apnea-hypopnea index (n/hour)	Obstructive apneas (n/hour)	remarks
3.1	113.2	89.1	state after decompression operation at the age of 9 months, subduro-peritoneal shunt because of internal and external hydrocephalus
3.2	30.2	10.8	state after adenotonsillectomy 6 days before
3.3	104.6	85.1	oxygen therapy*
3.7	89.8	74.1	oxygen therapy*
3.9	44.1	0	NCPAP, pressure 5 hPa
3.9	31.9	0	NCPAP, pressure 6 hPa
4.8	19.7	0	NCPAP, pressure 5 hPa
5.5	16.6	0.1	NCPAP, pressure 5 hPa
5.5	18.5	0	NCPAP, pressure 8 hPa
11.5	2.7	0	NCPAP, pressure 8 hPa
11.7	2.2	0	spontaneous respiration without NCPAP

\*- oxygen supplementation via funnel, controlled by pulse oximetry

Series of cases

This series of cases includes all children with skeletal dysplasia caused by FGFR3 mutations examined in the sleep laboratory of the Vestische Kinder- und Jugendklinik Datteln in the course of 20 years (January 1990 - January 2009). The clinical data are sum-

marised in table 2. The patients were 3.0 years old at first PSG (median 3.0; IQR 0.6 to 6.6 years; range 8 days to 15.0 years). Anamnestic data are summarised in table 3. Susceptibility to infections with repeated infections of the upper and lower respiratory tract were found in 8/24 patients (33.3%).

Table 2. Clinical data (\*) (children with adenotonsillar hyperplasia [14] versus achondroplastic children)

	children with adenotonsillar hyperplasia	children with achondroplasia	p (U-test)
n	62	24	
male/female	38/24	13/11	11
age (years)	4.5 (2-5.8)	3 (0.606.6)	n.s.
gestational age (complete weeks)	40 (37-40)	40 (38-40)	n.s.
birth weight (g)	3155 (2455-3550)	3420 (3100-3800)	n.s.
actual weight (kg)	17 (11.5-23.5)	11.4 (7-20)	n.s.
actual length (cm)	104 (89-120)	79 (66-102)	<0.05

(\*) median and interquartile range (in brackets)

n.s. = The difference is not statistically significant

Table 3. Historical complaints and symptoms in 24 children with achondroplasia and hypochondroplasia compared with the general population

Complaint/Symptom	Achondroplasia		General population	Remarks (author)
	n/n	%	%	
Daytime symptoms:				
recurrent respiratory infections	8 out of 24	33.3	2-4	8-11 years [23]
tiredness	4 out of 24	16.7	3.7	1-6 years [11]
			1-3	8-11 years [23]
concentration problems	3 out of 24	12.5	2.4	1-6 years [11]
morning headaches	1 out of 24	4.2	-	-
Sleep-related symptoms:				
snoring (every sleep period)	17 out of 24	70.8	9.1	1-6 years [11]
excessive sweating	15 out of 24	62.5	6.4	1-6 years [11]
mouth breathing	13 out of 24	54.2	8.1 (daytime)	1-6 years [11]
observed apneas	7 out of 24	29.2	<1	0-6 months [19]
laboured breathing	6 out of 24	25	2	0-6 months [19]
reclined head position	4 out of 24	16.7	3.5	1-6 years [11]
problem of maintaining sleep	2 out of 24	8.3	3-6	8-11 years [23]
hyperactivity	2 out of 24	8.3	4	0-6 months [19]
vomiting	2 out of 24	8.3	2	0-6 months [19]
coughing	2 out of 24	8.3	1	0-6 months [19]
cyanosis	1 out of 24	4.2	<1	0-6 months [19]
problem of initiating sleep	1 out of 24	4.2	6-10	8-11 years [23]
bruxism	1 out of 24	4.2	4	8-11 years [23]
extreme pallor	1 out of 24	4.2	8.1	1-6 years [11]

Daytime symptoms suggestive of SRD were found in 4/24 patients (16.7%), i.e. at least one of the following symptoms was present: daytime somnolence, attention and concentration problems, behavioural problems, and morning pallor (table 3). Sleep-related symptoms were present in 18/24 patients (75%), i.e. at least one of the following symptoms was present: snoring, mouth breathing, cyanosis, observed apneas, excessive sweating, enuresis, problems of initiating and maintaining sleep (table 3).

Prior to the first PSG, 11/24 patients (45.8%) had undergone adenoidectomy, 1/24 (4.2%) tonsillectomy, 2/24 (8.3%) adenotonsillectomy, 3/24 (12.5%) liquor drainage, and 6/24 (25%) a craniocervical decompression operation to treat foramen magnum stenosis.

Clinical examination prior to PSG revealed hypertrophied tonsils in 11/24 patients (45.8%), disturbed nasal breathing in 8/24 patients (33.3), and enlarged

cervical lymph nodes as a sign of chronic tonsillitis in 5/24 patients (20.8%).

PSG findings were abnormal in 19/24 patients (79.2%) with a nadir of oxygen saturation (pulse oximetry) ( $\text{SaO}_2$ ) below 90% and/or a nadir of transcutaneous partial pressure of oxygen ( $\text{tcpO}_2$ ) below 45 mmHg. Pathologic PSG findings were found in 10/24 patients (41.7%). The two children with the clinical picture of hypochondroplasia had a normal PSG. We diagnosed a central sleep apnea syndrome with > 100 apneas/hour sleep in a 8 days old infant. OSAS with more than 5 obstructive apneas with a duration of more than 5 sec. was diagnosed in 8/24 patients (33.3%), 3 of these patients were suffering from severe OSAS. One of these 3 patients was admitted to our hospital in a life-threatening condition (case report 1). Hypoventilation with  $\text{SaO}_2$  below 90% and  $\text{tcpO}_2$  below 45 mmHg was seen in 1/24 patients (4.2%). The polysomnographic data are summarised in table 4.

As a consequence, the following therapeutic interventions were performed: AT in 1/24 patients (4.2%), tonsillectomy (TE) in 2/24 (8.3%), ATE in 2/24 (8.3%), and nasal CPAP (continuous positive airway pressure) and BiPAP therapy (bilevel positive airway pressure), respectively, in 3/24 patients (12.5%). Table 5 shows the polysomnographic data before and after ENT-surgery. A significant improvement of the polysomnographic parameters was not seen when comparing these groups.

The anamnestic, clinical, and polysomnographical data of the 24 patients with achondroplasia and hypochondroplasia in this case series were collected in the course of 20 years. The methods of collecting data, the polysomnographical recording techniques, and the evaluated parameters did not change considerably in the sleep laboratory of the Vestische Kinder- und Jugendklinik Datteln in this period of time [9,15,22].

The heterogeneity of achondroplasia concerning the clinical symptoms has also been described regarding form and severity of SRD in these patients [8,13,17,18,21,24]. On the basis of clinical findings, Tasker et al. [18] differentiated between three types of SRD with different prognosis in children with achondroplasia and related these to different forms of disturbed ossification in the cranial base: In type 1 according to Tasker [18], there is solely "relative" adenotonsillar hypertrophy caused by a degree of midfacial hypoplasia, which results in obstructive sleep apnoea that clinically resolves with adenotonsillectomy. This type is related to rostral or late developmental defects of the cranial base. In type 2 according to Tasker [18] there is muscular upper airway obstruction along with progressive hydrocephalus, which could have as a common aetiology jugular foramen stenosis related to intermediary defects in the enchondral ossification of the cranial base. In type 3 according to Tasker [18] foramen magnum and/or hypoglossal foramen abnormalities are seen, resulting in muscular upper airway obstruction without hydrocephalus, further compounded by the effects of gastro-oesophageal reflux and the development of cor pulmonale.

Twenty of the patients described in our case series can be allocated to type 1 according to Tasker, 3 patients (case report 2) to type 2, and 1 patient to type 3 (case report 1). Regular snoring and increased daytime somnolence are the anamnestic leading symptoms for OSAS [11,14,23]. However, the registration of daytime symptoms is dependent on the degree of

suffering and on the attitude of the patient towards his or her disease. The registration of sleep-related symptoms is dependant on the quality of third party assessment by the parents or caregivers. The percentage of children in our case series demonstrating daytime symptoms (15.7% daytime somnolence) and sleep-related symptoms, especially snoring (70.8%), was high in comparison to the data in the literature (table 3). Snoring at nights was reported in 58 to 100% [13,18,21,24], daytime somnolence was reported in singular cases only (5-11%) [17,21,24]. This points towards considerable underreporting. Waters et al. [21] tried explaining the origin of this recall bias: The complaints were chronic and were regarded as "belonging to life with achondroplasia" by the patients. A further reason for a bias in case series with relatively small numbers of patients is the selection process. In questionnaires only living patients can be evaluated, dead patients with symptoms suggestive of OSAS cannot be included. Therefore, studies based on questionnaires tend to underestimate symptoms suggestive of OSAS. On the other side, polysomnographic studies tend to recruit patients with anamnestic complaints or clinical symptoms, thereby overestimating OSAS. Deaths in patients with achondroplasia are probably underestimated in both kinds of studies. This underlines the necessity for studies comprising the complete population of patients with achondroplasia and the necessity of a structured medical history in these patients. Regarding the sleep-related symptoms, especially excessive sweating at night was not mentioned in the literature, whereas it was reported in 62.5% of the children in our case series (table 3).

We compared the group of patients with achondroplasia to a cohort of children with adenotonsillar hypertrophy, who had undergone polysomnography before and after adenoidectomy and/or tonsillectomy (table 2) [14] and found that the apnea-hypopnea-index was not significantly higher, whereas the OSA-index and maximal transcutaneous partial pressure of carbon dioxide ( $\text{tcpCO}_2$ ) were significantly higher. Minimal  $\text{SaO}_2$  and  $\text{TcpO}_2$  were significantly lower (table 4). The majority of patients with achondroplasia with pathological PSG were diagnosed to have OSAS, with exception of an 8 days old infant with central apnea syndrome with excessive periodic breathing and a patient with hypoventilation without apneas. OSAS was improved in the patients allocated to type 1 according to Tasker, as described by other authors [3,18]. In our case series, we only had 5 PSG before



ENT surgery and 4 PSG after ENT surgery (table 5), including 2 patients with severe OSAS (case reports 1 and 2), which had to be treated with CPAP and BiPAP therapy after the operation. This explains the fact that

the improving effect of adenoidectomy and/or tonsillectomy was not statistically significant when comparing the groups. Minimal values for SaO<sub>2</sub> and TcpO<sub>2</sub> were actually lower postoperatively (table 5).

Table 4. Polysomnographical data (\*) (pre- and postoperative data of children with adenotonsillar hyperplasia [14] versus achondroplastic children)

	children with adenotonsillar hyperplasia		children with achondroplasia
	preoperative (n=62)	postoperative (n=62)	(n=24)
Total sleep time (hours)	6.7 (6.1-7.5)	6.6 (6.0-7.2)	5.9 (5.4-6.9)
apnea-hypopnea index (n/hour)	23 (9.8-27.5)**	8 (4.9-10.7)	5.1 (2.4-13.7)
obstructive apneas (n/hour)	12 (1.1-8.5)**	0 (0-0)	0.2 (0-6.4)**
nadir of oxygen saturation (%)	75 (81-90)**	90 (90-94)	86 (79-89)**
minimum of TcpO <sub>2</sub> (mmHg)	38 (31-51)**	50 (35-63)	38 (34-45)**
maximum of TcpCO <sub>2</sub> (mmHg)	56 (46-62)**	47 (45-48)	49 (42-62)**

(\*) median and interquartile range (in brackets)

\*\* In comparison with the group „postoperative“ ist he difference not statistically significant (p<0.05, U-test)

Table 5. Results of polysomnographic sleep recordings before and after ENT surgery (ATE: 2 patients; TE: 2 patients; AT: 1 patient)

parameter	PSG preoperative (n=5)		PSG postoperative (n=4)		p (U-test)
	median	IQR	median	IQR	
age (years)	2.9	1.8-5.0	3.5	2.9-8.3	-
Time interval to surgery (days)	20	17-25	18	4-365	-
total sleep time (min.)	352	323-410	373	194-403	n.s.
apnea-hypopnea index (n/hour)	11.4	9.3-102.3	24.8	11.8-48.5	n.s.
mean duration of apneas (s)	7.1	5.1-8.5	8.1	7.0-9.5	n.s.
longest apnea (s)	21	10.5-37.5	20.5	18-27	n.s.
obstructive apneas (n/hour)	8.3	3.8-84.3	14.7	6.0-41.9	n.s.
mean duration of OSA (s)	8.6	5.1-9.5	6.4	5.3-8.9	n.s.
longest OSA (s)	21	10.5-37.5	20.5	18.5-27	n.s.
nadir of SaO <sub>2</sub> (%)	81	67-91	68	38-78	<0.05
minimum of TcpO <sub>2</sub> (mmHg)	41	39-44	37	20-41	<0.05
maximum of TcpCO <sub>2</sub> (mmHg)	56	49-61	53	51-58	n.s.

n.s. = The difference is not statistically significant

Our findings support the concept that SRD, partially in life-threatening developments, are a relevant complication in children and adolescents with achondroplasia [3,4,8,10,13,16-18,21,24].

When the medical history is suggestive of SRD, as it is the case more often in patients with achondroplasia in comparison to the general population [11,19,23], a PSG should be performed immediately. Moreover, it seems advisable to perform PSG in all children with achondroplasia in early childhood [1].

At least in a part of the patients with achondroplasia, the pathophysiological mechanisms of OSAS are connected with the etiology of achondroplasia (midfacial hypoplasia, disturbed ossification of the cranial base). The OSAS in achondroplastic children and adolescents could not be improved by an ENT operation in all cases. In 3/24 patients (12.5%) a therapy with CPAP/BiPAP was necessary.

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## SUMMARY

### DIAGNOSTICS AND MANAGEMENT OF SLEEP-RELATED RESPIRATORY DISTURBANCES IN CHILDREN WITH SKELETAL DYSPLASIA CAUSED BY FGFR3 MUTATIONS (ACHONDROPLASIA AND HYPOCHONDROPLASIA)

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To evaluate the frequency of clinical indicators for sleep-related respiratory disturbances (SRD) and the polysomnographical manifestations of these disorders in children with skeletal dysplasia caused by FGFR3 mutations.

From January 1990 to January 2009, 24 patients (22 achondroplasia, 2 hypochondroplasia; 13 boys, 11 girls; age 8 days to 15 years, median age 3.0 years) were examined, including a semi-structured interview, a clinical examination, and a polysomnographic sleep recording (65 polysomnographic sleep recordings (PSG) in 24 patients). We performed PSG in a subgroup of five patients before and after adenoidectomy (AT) and/or tonsilectomy (TE).

Daytime symptoms suggestive of SRD (daytime somnolence, attention and concentration problems, behavioural problems, and pallor) were found in 4/24 patients (16.7%). Sleep-related symptoms (snoring, mouth breathing, cyanosis, observed apneas, excessive sweating, enuresis, problems of initiating and maintaining sleep) were present in 18/24 patients (75%). Prior to the first PSG, 11/24 patients (45.8%) had undergone AT, 1/24 (4.2%) TE, 2/24 (8.3%) adenotonsilectomy (ATE), 3/24 (12.5%) liquor drainage, and 6/24 (25%) a craniocervical decompression operation.

Clinical examination prior to PSG revealed hypertrophied tonsils in 11/24 patients (45.8%), disturbed nasal breathing in 8/24 patients (33.3), and enlarged cervical lymph nodes as a sign of chronic tonsillitis in 5/24 patients (20.8%). PSG findings were abnormal in 19/24 patients (79.2%) with a nadir of oxygen saturation (pulse oximetry) below 90% and/or a nadir of transcutaneous partial pressure of oxygen below 45 mmHg. Pathologic PSG findings were found in 10/24 patients (41.7%): obstructive sleep apnea syndrome (OSAS) was diagnosed in 8/24 patients (33.3%), central sleep apnea syndrome in 1/24 patients (4.2%), and hypoventilation in 1/24 patients (4.2%). As a consequence, the following therapeutic interventions were performed: AT in 1/24 patients (4.2%), TE in 2/24 (8.3%), ATE in 2/24 (8.3%), and nasal continuous positive airway pressure (continuous positive airway pressure) and bilevel positive airway pressure therapy (bilevel positive airway pressure), respectively, in 3/24 patients (12.5%).

SRD, especially OSAS, represent a complication of clinical and prognostic relevance in children with achondroplasia. We therefore think that not only those children with a history suggestive of SRD, but all achondroplastic children should be evaluated by PSG.

At least in a part of these patients, the pathophysiological mechanisms of OSAS are connected with the etiology of achondroplasia. Achondroplastic children with OSAS, who do not benefit from AT and/or TE,

should be treated with NCPAP therapy.

**Key words:** Sleep-related respiratory disturbances, achondroplasia, hypochondroplasia.

## РЕЗЮМЕ

### ДИАГНОСТИКА И КОРРЕКЦИЯ ДЫХАТЕЛЬНЫХ РАССТРОЙСТВ ВО ВРЕМЯ СНА У ДЕТЕЙ СО СКЕЛЕТНЫМИ ДИСПЛАЗИЯМИ, ВЫЗВАННЫМИ МУТАЦИЯМИ FGFR3 (АХОНДРОПЛАЗИЯ И ГИПОХОНДРОПЛАЗИЯ)

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Целью исследования явилось определение частоты клинических проявлений дыхательных расстройств, связанных со сном, а также выявление характерных полисомнографических показателей у детей со скелетными дисплазиями, вызванными мутациями FGFR3 (ахондроплазия и гипохондроплазия).

С января 1990 г. по январь 2009 г. обследовано 24 больных: 22 - с ахондроплазией и 2 - с гипохондроплазией. Из них: 13 мальчиков и 11 девочек в возрасте от 8 дней до 15 лет (средний возраст - 3,0 года). Исследование включало полуструктурированное интервью, клиническое обследование и полисомнографические исследования (65 полисомнографических записей у 24 больных). Была выделена группа из 5 пациентов, которым до и после аденоидэктомии (АЭ) и/или тонзиллэктомии (ТЭ) проводили полисомнографическую регистрацию сна (ПРС).

Симптомы "дневного" проявления дыхательных расстройств во время сна наблюдались у 4 из 24 пациентов (дневная усталость, проблемы связанные с нарушением внимания и концентрации, поведенческие проблемы, бледность). Симптомы, относящиеся к расстройству сна (храп, дыхание ртом, цианоз, наблюдаемые задержки дыхания, чрезмерная потливость, энурез, проблемы засыпания и сохранения сна) имели место у 18 (75%) из 24 пациентов. Перед первой ПРС 11 (45,8%) из 24 пациентов была проведена АЭ; одному (4,2%) из 24 - ТЭ; 2 (8,3%) - аденоидтонзиллэктомия (АТЕ), 3 (12,5%) - дренаж ликвора, 6 (25%) - де-

компрессивная краниоцервикальная операция. Клиническое обследование до ПРС у 11 (45,8%) из 24 пациентов выявило гиперплазию миндалин, у 8 (33,3%) из 24 - нарушение носового дыхания, у 5 (20,8%) из 24 - увеличение шейных лимфатических узлов, как признак хронического воспаления миндалин. У 19 (79,2%) из 24 пациентов было выявлено нарушение показателей ПРС (надир SaO<sub>2</sub> <90% и/или надир tcpO<sub>2</sub> <45 mmHg).

Патологические показатели ПРС были выявлены у 10 (41,7%) из 24 пациентов. Синдром обструктивного апноэ сна (СОАС) был диагностирован у 8 (33,3%) из 24 пациентов; центральный синдром апноэ - у 1 (4,8%) из 24; гиповентиляция - у 1 (4,8%) из 24. В результате были осуществлены следующие терапевтические вмешательства: АЭ провели одному (4,2%) из 24 пациентов, ТЭ - двум (8,3%) из 24, АЭ - двум (8,3%) из 24, носовое продолжительное положительное дыхательное давление и двухуровневая терапия положительным дыхательным давлением соответственно 3 (12,5%) из 24 пациентов.

Связанные со сном дыхательные расстройства (ССДР), в особенности СОАС, представляют собой клинически и прогностически значимые осложнения у детей с ахондроплазией. Делается вывод о необходимости проведения ПРС всем детям с ахондроплазией, особенно в тех случаях, когда патофизиология ССДР связана с ахондроплазией. Детям с ахондроплазией и ССДР, которым АЭ и/или ТЭ не помогли, должна проводиться терапия продолжительным положительным воздушным давлением.



## რეზიუმე

FGFR3 მუტაციით გამოწვეული ჩონჩხის დისპლაზიის (აქონდროპლაზია და ჰიპოქონდროპლაზია) მქონე ბავშვებში ძილთან ასოცირებული რესპირატორული დარღვევების დიაგნოსტიკა და მართვა

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ვ. ანდლერი

ძილის შემსწავლელი ლაბორატორია, ბავშვთა და მოზარდთა კლინიკა, ვესტ/დატელნი ვიტენ/ჰერდეკეს უნივერსიტეტი, გერმანია

კვლევის მიზანს წარმოადგენდა FGFR3 მუტაციით გამოწვეული ჩონჩხის დისპლაზიის მქონე ბავშვებში ძილთან ასოცირებული რესპირატორული დარღვევების (ძარდ) კლინიკური ინდიკატორებისა და პოლისომნოგრაფიული გამოვლინებების სიხშირის დადგენა.

1990 წლის იანვრიდან 2004 წლის იანვრის ჩათვლით კვლევაში ჩართული იყო 24 პაციენტი, მათ შორის 22 აქონდროპლაზიისა და 2 ჰიპოქონდროპლაზიის დიაგნოზით. პაციენტებიდან 13 იყო ვაჟი და 11 გოგონა. ასაკი - 8 დღიდან 15 წლამდე, საშუალო ასაკი - 3,0 წელი. ყველა შემთხვევაში აღებულ იქნა ნახევრად სტრუქტურირებული ინტერვიუ, ჩატარდა სრული კლინიკური გამოკვლევა და ძილის პოლისომნოგრაფიული რეგისტრაცია (ძპრ) (65 პოლისომნოგრაფიული ჩაწერა 24 პაციენტში). 5 პაციენტისაგან შემდგარ ქვეჯგუფში ძპრ გაკეთდა აღენოდექტომიისა (აე) დ/ან ტონზილექტომიის (ტე) ოპერაციებამდე და შემდეგ.

ძარდ-ის დღის პერიოდისათვის დამახასიათებელი სიმპტომები (ძილიანობა, ყურადღებისა და კონცენტრაციის დაქვეითება, ქცევითი პრობლემები, სიფერმკრთაღე) დადგენილ იქნა 24-დან 4 (16,7%) შემთხვევაში. ძილთან ასოცირებული სიმპტომები (ხვრინვა, პირით სუნთქვა, ციანოზი, აპნოე, ჭარბი ოფლიანობა,

ენურეზი, დაძინებისა და ძილის შენარჩუნების პრობლემები) აღენიშნა 18/24 პაციენტს (75%). პირველ ძპრ-მდე 11/24 პაციენტს (45,8%) გაუკეთდა აე; 1/24 (4,2%) - ტე; 2/24 (8,3%) - აე და ტე, 3/24 (12,5%) - ლიქვორის დრენაჟი, 6/24 (25%) - მადეკომპრესირებელი კრანოცერვიკალური ოპერაცია. ძპრ-მდე კლინიკური გამოკვლევისას ნუშურების ჰიპერტროფია გამოუვლინდა 11/24 პაციენტს (45,8%), ცხვირით სუნთქვის დარღვევა - 8/24 პაციენტს (33,3 %), კისრის ლიმფური კვანძების გადიდება (როგორც ქრონიკული ტონზილიტის ნიშანი) - 5/24 პაციენტს (20,8 %). 19/24 პაციენტიდან (79,2%) ძპრ მონაცემები სცილდებოდა ნორმას (SaO<sub>2</sub>-ის ნადირი, უდაბლესი დონე 90%-ზე ნაკლები და/ან tcpO<sub>2</sub>-ის ნადირი, უდაბლესი დონე 45 მმგ-ზე ნაკლები). ძპრ პათოლოგიური მაჩვენებლები დადგენილ იქნა 10/24 პაციენტში (41,7%); ძილის ობსტრუქციული აპნოეს სინდრომი (ძოას) დიაგნოსტირებული იყო 8/24 შემთხვევაში (33,3%), ძილის ცენტრალური აპნოეს სინდრომი 1/24 პაციენტში (4,2%) და ჰიპოვენტილაცია 1/24 პაციენტში (4,2%). განსორციელებული იყო შემდეგი სამკურნალო ჩარევები: ტე - 2/24-ში (8,3%), აე და ტე - 2/24-ში (8,3%), ცხვირით სუნთქვითი გახანგრძლივებული თერაპია დადებითი წნევით და ორდონიანი სუნთქვითი თერაპია დადებითი წნევით შესაბამისად 3/24 პაციენტში (12,5%).

ძარდ და, განსაკუთრებით, ძოას აქონდროპლაზიის მქონე ბავშვებში კლინიკურად და პროგნოზულად მნიშვნელოვანი გართულებაა. აქედან გამომდინარე მიზანშეწონილად მიგვაჩნია ძპრ ჩატარდეს არა მხოლოდ მაშინ, როცა ძარდ-ზე ეჭვი გვაქვს, არამედ აქონდროპლაზიის ყველა შემთხვევაში. შემთხვევათა ნაწილში მაინც ძარდ პათოგენეზურად აქონდროპლაზიასთანაა დაკავშირებული. აქონდროპლაზიის მქონე ბავშვებს, რომელთაც აე და/ან ტე არ უშველა, უნდა ჩაუტარდეთ ცხვირით სუნთქვითი გახანგრძლივებული თერაპია დადებითი წნევით.



## MANAGING SLEEP DISORDERS IN CHILDREN: WHICH IS THE BEST STRATEGY ?

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Childhood sleep disturbances involving difficulties in initiating or maintaining sleep trouble 15-35% of children under the age of 3 [11,25,33,38]. These disorders may affect the family stability [23,28] and arises from problems controlling emotions until psycho-pathology insurgence and if untreated, may persist in time [8].

Childhood sleep is subjected to considerable changes, as is necessary to complete the transition into maturity that is present in adulthood [38].

Organizing the sleep state and the awakening arises from the caregiving system: the regular dyadic relationship between mother and child ,in fact, the sequence of the daily routine of biological state. The caregiver calms the child and strengthens the relationship that benefits the sense of self and the auto-regulation of the infant [4].

Like the major part of the developmental process, sleep disruptions arise from extrinsic factors (ex. the sleep practices of the parents) and intrinsic (ex. the temperament). The first could be modified from behavioral strategies [29], therefore intervening the sleep problems in children should include the evaluation of attitudes and parenting skills [33]. In fact, it was demonstrated that the direct treatment and aim of the sleep problems could also improve other function domains [9].

The new social habits determine a discrepancy between what should be the natural rhythm of sleep and awakenings of the child and the same social needs [5]. Indeed, they have brought physical developmental problems and/or tied to the irregularity of sleep that already develops from the first year of life.

The persistence of a sleep disorder over time requires early intervention and effective measure to improve the problem without neglecting the importance of prevention parental education, addressing the parents' (or parental figure) approach to their child's sleep [30].

In literature, there are several studies showing the effectiveness of cognitive-behavioral treatment of childhood sleep disorders. These approaches can be used either alone or in combination with pharmacotherapy [18,27-29,31]. The primary objective of cognitive-behavioral therapy helps children to improve sleep, regardless of medical interventions [15]. Given the high predominance of sleep disorders in children, it is important to know the most appropriate strategies and effective treatment. This review aims to critically analyze the literature studies showing the effectiveness of cognitive-behavioral strategies in the treatment of sleep disorder during the developmental age. These approaches are based on the principles of theoretical learning (such as extinction), according to several studies and meta-analysis, would be effective [8]. To access the empirical evidence of such treatments, the APA (American Psychological Association) developed a criteria that characterizes the effective treatments at an experimental level. These criteria allow you to determine which category falls into a particular type of treatment [7]. Thanks to the “Chambless Criteria,” many effective research was carried out, lead with different samples from children who had difficulty sleeping, which have demonstrated the validity of the cognitive-behavioral approach.

Finally, despite the positive results of the analysis in literature, the research needs further evidence demonstrating the validity of cognitive-behavioral strategies in the long term. Precisely for this reason, it would be appropriate to conduct studies with a longer time period that exceeds twenty-four/thirty months.

*Cognitive-behavioral intervention of sleep disorders in children.* Before a presumptive sleep disturbance is treated, it must be determine that the sleep problem constitutes a behaviorally or medically based sleep disorder and is not a symptom of another primary medical problem. In fact, the etiology of sleep disturbance should be clarified in as much detail as possible because cognitive-behavioral treatment should address the specific underlying causes of the sleep

disturbances to be effective. The thorough evaluation of sleep disorders is the first essential step in deciding whether to use a cognitive-behavioral intervention or whether the child needs pharmacotherapy [28,31].

According to the DSM-IV, sleep disorders are classified into; Dyssomnias and Parasomnias. The Dyssomnias are primary sleep disorders characterized by hyper-somnolence, insomnia or excessive drowsiness and are caused by an alteration of the quantity, quality, or sequence sleep time. The Parasomnias are disorders characterized by abnormal behavior or physiological events that occur during sleep, specific stages of sleep, or in the sleep-wake phase. Unlike the Dyssomnias, the Parasomnias do not involve mechanical abnormalities that cause the states of sleep/wake and that regulate the time cycle of sleep and wakefulness. Instead, the Parasomnias represent the activation of physiological systems at inappropriate hours during the sleep-wake cycle. In particular, these disorders involve activation of the autonomic nervous system, motor system, and cognitive processes during sleep or during the transition between sleep/wake.

One limitation of the cognitive-behavioral invention may be the difficulty to maintain the improvement achieved over time.

The use of behavioral strategies to alleviate sleep disorders is based on the belief that parents play an important role in the development and maintenance of sleep difficulties. As a treatment plan, the parents, as well as children, learn to modify their behavior to help their child sleep [30].

*Review of Literature.* Various studies have demonstrated the effectiveness of cognitive- behavioral treatment for sleep disorders in children, especially in regard to insomnia during the first and second stages of childhood. These studies have reinforced the benefits of such techniques in daytime functioning and the well being of the patient's family [29].

The major part of the studies presented in this review have been subjected to the criteria of Chambless [7] in order to assess whether a technique is effective. According to these criteria, it could take three important decisions. In the first place, a technique is well-defined if at least two experiments "design single-case" have demonstrated it's valid and if the last study was confirmed from two investigators or from different investigating teams. In second place, if two experiments

document that the treatment is more effective than no treatment (detected by analyzing a control group) the criteria in the same treatment are met (also if only it is confirmed by one investigator) and the intervention is considered "probably effective." Lastly, if at least one study is effectively controlled and another study is found in a less rigorous or if two or more searches are performed with small sample sizes the techniques will be assessed as "promising intervention" (ibidem).

Many studies of cognitive-behavioral intervention for sleep disorders have been evaluated in "design study" (case history, single cases and random studies and controlled); the most significant concern extinction, graduated extinction, bedtime routine, schedule awakenings and preventive parental education. In addition to being evaluated individually, these techniques have been considered as part of a multicomponent treatment plan.

*Extinction and graduated extinction.* The first studies on the treatment of childhood sleep disorders, includes inability to fall asleep and night awakenings, have focused on the use of extinction [28]. Extinction consists of brief periods during which parents ignore the child expect for safety purposes. The parents put the child to bed with at a designated bedtime and not intervening when the child cries until a set time the next morning. The risk is that the method is interrupted because of the parent's ability to ignore their child crying and that results in a further reinforcement of the disorder [21,25,26]. The first to study this technique was Williams [29] who instructed the parents of 21 months girl, to put their daughter to bed in a "relaxing and pleasant way "and not to return if the child woke up and cried. The results of the experiment are based on the duration that the child cried (that diminished with time) reported by the parents and calculated in minutes. It was also confirmed by subsequent studies (table 1) made with bigger sample sizes and control groups. The effective treatment was also demonstrated by three research groups in separate studies between-subject and random, like Rickert and Johnson [32] reiterate that extinction is as effective in children with nocturnal awakenings. The results of this study are based on the parental relationship, their diaries, and a control group that was added for reliability. The extinction was more effective by decreasing nighttime awakenings in the treatment group than in the control group that led to a faster improvement than the scheduled awakenings. Subsequent studies were conducted on a larger scale (45 children from 7 to 27 months) from France and associate [12,13]. In this study, twenty three participants were

consecutively subjected exclusively to extinction. The other twenty two participants were randomly assigned to extinction associated with drug trimprazine, natural extinction or programmed bedtime routine where once in bed were interfered by the parents, unless it was considered absolutely necessary [14]. The results are

based on the parent's diary with the inclusion of a reliability check using a voice activated relay (VOR) for a subgroup of subjects; the parents and the recordings from the VOR complied 91%. All patients were successfully treated, including the group with extinction combined with pharmacotherapy.

Table 1. Summary of Literature on Treatment with Extinction (In: Mindell, 1999)

Article	Subjects	Assessment	Control	Follow-up	Outcome
Williams (1958)	1F 21 mos	Diary of sleep	None	2 yrs	Extinction effective in dec duration of crying at bedtime
Rapoff et al. (1982)	6 24-54 mos	audiotape	---	7-15 mos	Effective for 50% of subjects
Seymour et al. (1983)	208 0-6 yrs	diary; parent report	None	6 mos	Effective for 78% of subjects
Chadez & Nurius (1987)	1 F 7 mos	diary; parent report	-----	47 days	xtinctioneffectiveonly withcognitive restructuring for parents
Rickert & Johnson (1988)	33 6-54 mos 18m, 15F	diary of sleep	ontrol/sched awaken.	6 weeks	Extinction = scheduled Awakenings > control Extinction quicker Results
Seymour et al. (1989)	45 9-60 mos 28M, 17F	between- group	wait-list control	3 mos	Compared written instruction to therapist-guided
France & Hudson (1991)	7 8-20 mos 5M, 2F	diary; quest; recording device	-----	3 mos; 2 yrs	Significant improvement in night waking
France et al. (1991) /France (1992)	45 7-27 mos 17M, 18F	Diary of sleep	Extinction 1 med/ placebo	6, 18, or 30 mos	Ext , effective than ext 1 drug; More effective than placebo
Mindell (1999)	---	Review of literature (41 study)	-----	-----	Efficacy of cognitive- behavioral therapy
Owens et al. (2006)	-----	Review of literature	-----	-----	Efficacy of extinction and extinc- tion graduated
Matthey et al. (2007)	Childhood 6-18 months	Study controlled	-----	-----	Efficacy of cognitive- behavioral therapy
Matthey et al. (2009)	-----	Review of literature	-----	-----	Efficacy of extinction

Subsequently, a follow up study was conducted from France [13] with the same participants after six and thirty months, respectively compared with thirteen and fifteen control groups who did not receive the treatment. Significant improvements were seen during the follow-up in the treated group and no change in the control groups. On a larger scale, further studies were conducted by Seymour and colleagues. In their first study [36] the authors showed that a treatment program with several components, such as onset of bedtime routine, bedtime routine, and ignore the baby's crying reduced the sleep disorder of two hundred and eight children. It also used a within-subjects design and the comparison between baseline and post-treatment diary indicated a significant improvement in

78% of the participants (children aged 8-20 months). In the end, Chadez and Nurius [6] evaluated the success of the extinction treatment (made on 7 months old girl) for seven months and found the technique to be successful. Taking into consideration, the parent's response with cognitive restructuring demonstrating that extinction is successful when it is associated to the parent's intervention.

The extinction procedure could be very stressful for parents as they often are not willing to hear their baby cry for long periods of time and for this reason other studies have supported the use of two techniques: extinction and gradual extinction with parental presence [37].

The extinction with parental presence is an effective technique and more acceptable with parents. It is based on the assumption that sleep disorders in children are also caused by separation anxiety. The program provides a similar structure as the standard extinction with the difference being that the parent remains in the room with the child during the procedure. The parent's presence reassures the child allowing a sweet sleep and reducing the nocturnal awakenings. Extinction with parental presence is a more gentle extinction standard, but requires more time for the application because the parents should prepare before, for at least seven nights, and in order to avoid intervening if the child cries and in that way the disorder is reinforced. It has been verified that the extinction with parental presence has improved the sleep of babies and children up to two years and decreasing nocturnal awakenings and therefore increasing the amount of sleep [11,15,22,34]. However, gradual extinction aims to achieve the desired behavior with small achievements, such as delay or a gradual advance in the time needed to fall asleep. In addition, the child

becomes accustomed to the distance from their parents at the moment of going to bed. The methods require a lot of time and have a long application time, for this the risk is that the parents don't apply the method constantly. Contrary, the positive aspect is that it is easier for the parents who can't tolerate the other methods [5].

Like in the standard extinction, the phasing is considered effective and this has been verified through a series of random and controlled trials (table 2). The first randomized study was conducted by Adams and Rickert [2] with a sample of thirty six children (18-38 months) who attended primary school. The result is in favor of the technique and graduated extinction of the bedtime routine that can be equally effective in reducing the difficulty of falling asleep. In Adams and Rickert's study, the parents were instructed to ignore their children's tantrums in the crib for certain periods of time (the length of time was determined based on the age of the child and the time at which the parents believed they could ignore it).

Table 2. Summary of Literature on Treatment with Graduated Extinction ((In: Mindell, 1999)

Article	Subjects	Assessment	Control	Follow-up	Outcome
Rolider & Van Houten (1984)	3 24-30 mos 3M	Diary of sleep	————	70 days	Inc. duration to attend at bedtime; Effective for bedtime problems Not traditional grad. Extinction
Pritchard & Appleton (1988)	31 9-42 mos 19M, 12F	Diary of sleep	Control group	3 mos	Wait 10 or 20 min. before check; Effective
Adams & Rickert (1989)	36 18-48 mos 16M, 20F	diary; reliability ck	Control group	6 weeks	Checking technique; Equal to positive routine; more difficult for parents
Durand & Mindell (1990)	1F 14 mos	diary, videotape	————	9 mos	Checking technique; Effective
Lawton et al. (1991)	6 6-14 mos 2M, 4F	diary; reliability ck	————	120 days	Dec duration of attention at bedtime/ night wake; Improvements in 4/6 chil- dren; Decreased extinction burst
Mindell & Durand (1993)	6 18-52 mos 4M, 2F	diary, videotape	————	1 mos	Checking technique at bedtime; Treatment at bedtime generalized to night waking s
Sadeh (1994)	50 9-24 mos 28M, 22F	diary; acti- graph	none	3 week	Checking technique; Effective; Equal to parent cosleeping
Mindell (1999)	————	Review of literature (41 study)	————	————	Efficacy of cognitive-behavioral therapy
Owens et al. (2006)	————	Review of literature	————	————	Efficacy of extinction and extinction graduated
Matthey et al. (2009)	————	Review of literature	————	————	Efficacy of extinction grad.

The verification process allowed parents to comfort their child for fifteen seconds or less. The graduated extinction, like that of the bedtime routine is significantly more efficient in respect to the non treated group of control. The results are also based on the parental report, with an independent rater of bedtime behavior.

Following, Sadeh [34] demonstrated the efficiency of the gradual extinction with the study of fifty children (from 9 to 24 months) assigned randomly and a treatment of gradual extinction or with the intervention of cosleeping.

The results are based on the parent's diaries and actigraphy, a method that permits continued monitoring of the wake and sleep, thus representing a sufficient index objective of the sleep-wake cycle. The latter have shown that 60%

of children improved significantly during treatment and 52% showed significant improvement on the basis of actigraphy recordings without any major difference between the two interventions.

*Bedtime routine and programmed awakenings.* The bedtime routines involve parents organizing activities that will calm your child to sleep. According to the Chambless criteria [7], the latter can be considered a promising intervention. Several studies, though less than those made by the techniques mentioned about (table 3) showed that this technique could be effective, one of which is the previously mentioned experiment of Adams and Rickert [2]. Even Milan et al. [24] conducted bedtime routine on three children with disabilities (respectively 2, 4, and 15 years old) in a within-subject design.

Table 3. Summary of Literature on Treatment with Positive Bedtime Routines ((In: Mindell, 1999)

ARTICLE	SUBJECTS	ASSESSMENT	CONTROL	FOLLOW-UP	OUTCOME
Milan et al. (1981)	3 2-15 yrs 2M, 1F	diary; reliability ck	none	1-2 yrs	Severely handi- capped population
Adams & Rickert (1989)	36 18-48 mos 16M, 20F	Diary of sleep	Control group	6 week	Equal to grad extinct; easier for parents
Galbraith et al. (1993)	45 5-72 mos 28M, 17F	Diary of sleep	none	2-18 mos	70% success rate; 62% at follow-up
Mindell et al. (2009)	405 mother 206 childhood (7-18 mos) 199 childhood (18-36 mos)	BISQ (question- naire); Diary of sleep	Control group	3 weeks	Efficacy of rou- tine bedtime

Table 4. Summary of Literature on Treatment with Scheduled Awakenings (In: Mindell, 1999)

ARTICLE	SUBJECTS	ASSESSMENT	CONTROL	FOLLOW-UP	OUTCOME
McGarr & Hovell (1980)	1F 3 mos	Diary of sleep	none	none	Effective
Johnson et al. (1981)	3 9-12 mos 2M, 1F	Diary of sleep	-----	5-7 weeks	Effective; com- pliance problem for one
Johnson & Lerner (1985)	12 6-30 mos 9M, 3F	Diary of sleep	-----	2-3 mos	Effective; 77% compliance
Rickert & Johnson (1988)	33 6-54 mos 18M, 15F	Diary of sleep	control/ extinc- tion	6 weeks	Scheduled awakenings = extinction . con- trol; Extinction quicker results
Mindell et al. (2009)	-----	Review of literature	-----	-----	Effective of scheduled awak- enings



The focus of the parent's behavior was to send their children to bed crying as they reported themselves with the reliability of the observers. All three children found a significant improvement with treatment; however this study did not include a control experiment. Further studies, carried out by Germain et al. [16] demonstrated that the bedtime routine successful in treating 45 children (from 7 to 27 months) also if there wasn't a control group included. The authors used a within-subject design with the outcome based on the diaries completed by the parents.

Recently Mindell [27] and colleagues conducted a study that demonstrates that the first positive routine before falling sleep impacts these technique have on the child, on his sleep and maternal mood. 405 mothers with their children (206 children 7-18 months, 199 children 18-36 months) participated in this study. In the first week, the mothers were instructed to behave as they would normally behave with their child, while in the second and third weeks the mothers, in the experimental group, were taught the specific first positive bedtime routine technique. However, the control group continued to act as previously stated above. Throughout the duration of the experiment, the mother completed a questionnaire (BISQ: Brief Infant Sleep Questionnaire) and a sleep diary. The results found that the bedtime routine lead to significant reduction in sleep disorders for both infants and children. Significant improvements were observed on the latency sleep and the amount/duration of nighttime awakenings. Consequently, even the mother's mood improved significantly. The three weeks follow-up did not show significant changes. These results suggest that establishing a consistent positive routine, before falling asleep, is helpful for the child and for the sleep quality, especially for the continuity of sleep and the maternal mood.

Data reported from the studies state that scheduled awakenings are considered an effective program in treating parasomnias in children. These consist in understanding the times of spontaneous awakening of the child and educate parents to wake your child just before what should be the regular revivals, such as 10/15 minutes before, and then you put the child to sleep again. The technique is followed by steady increments of awakenings that led to longer periods of stable sleep. This technique was not frequently applied because the lack of the parent's participation [5]. In a large sample survey (n=33, children aged 6 to 54 months), scheduled awakenings we found to be more effective than no treatment: the research team got the best benefit compared to

the control group [32]. Previous studies [19] employed a multiple-baseline with three children of twelve months. The lack of crying was evident for two of the children whose parents had followed recommendations for successful treatment. However, the parents of the third child withdrew from the procedure.

*The importance of Preventive parent education.* Preventive education for parents has been demonstrated helpful in correctly affording childhood sleep disruptions, avoiding very common and frequent mistakes that parents (or caregivers) in good faith, might make. It is based on information and prevention programs that may prevent the development of sleep disorders. These programs are based on educating the parents on the sleep development and behavioral principles to prevent the sleep onset delay [5]. Typically, these methods are effective during the prenatal period and children up to 6 months [37].

Educating the parents met criteria treatment and this has been established by trial and error. Studies have demonstrated the effectiveness of prevention parental education in sleep disorders were those of Wolfson, Futterman, and Lacks [40], which randomly assigned 60 mothers and fathers waiting for their child (pre-childbirth), in an experimental and control group. Only on the experimental group, the educational training on sleep had been made prior to delivery. Using data from the diaries of parents, researchers found that 6-9 weeks old children of parents who had received training slept significantly better than the control group.

Adair et al. in 1993 have demonstrated the efficiency of the preventive education program based on behavioral strategies. They studied 164 infants of 4 months who went to a health visit, which accounted for the intervention group (where the training was done) and compared them with a control group of 128 children from the same age. After 9 months, the control group showed a greater likelihood of waking during the night compared to the experimental groups. All results are based on the diaries and reports from their parents. Finally, Kerr et al. [20] found that in children aged 3 to 9 months, whose parents were provided information on sleep, showed significantly fewer sleeping disorders than the control group. The operation was performed on the parents orally by a researcher with additional written material. The results were based on interviews with parents. Finally, it was shown that preventive parental education is faster and cheaper than the techniques previously mentioned [25,26].

*Uses of pharmacotherapy in children's sleep disorders.* Although the vast majority of children's sleep disorders will be resolved only with the cognitive-behavioral, a combination of that with pharmacological intervention might be more effective in certain clinical situations, for example children with ADHD or autism. The decision to use medicine should be considered when behavioral interventions were not effective and considering the child's medical history, the child's development, and weighing the relative risks and benefits of the patient.

In instituting drug therapy the following should be considered: a) heterogeneity etiology of insomnia b) the presence of contributing factors (psychopathological, biological, social, family) c) the need to always associate types of behavior treatments, relational psychodynamic d) the possibility of the habituation phenomena and suspension rebound e) the paradoxical effect of certain substances f) the parent's resistance against the drug [10].

A French investigation [25,26] demonstrated that 65% of generic medications and 56% of the pediatrics prescribe children medicine to sleep. The use of pharmaceuticals for sleep disorders are also very common in Italy, data from a recent national survey on the use of medication in children younger than 6 years have shown that 58.54% pediatricians and 61.21% of child psychiatrists most commonly use antihistamines (52.03% pediatricians, 22.14% child psychiatrists).

Pharmacotherapy treatment should be considered if the symptoms are so severe that they significantly interfere with daily life and an unsatisfactory response with other therapeutic approaches. These cases shouldn't wait until the disorder becomes chronic before prescribing a sedative or hypnotic drug. It is always better to refer to a short course of medication rather than to intervene later with a chronic disorder that requires a more complex and prolonged therapy that may led to energy impairment during the day and disturbances in family dynamics. In each case, the association with a cognitive-behavioral treatment seems to improve compliance. In children and adolescents, all the implications involving the relationship between the patient, the disorder, the drug and the doctor also extend to the family dynamics must be taken into consideration as they may affect the effectiveness of therapy. In fact, at the parent's request of

pharmaceuticals it is also appropriate that the doctor decipher what underlies the request, such as tension-type, aggression, or the realization of a mechanism of control over the child (ibidem).

An analysis of literature showed that the most effective treatment of sleep disorders, especially difficulties falling asleep and nighttime awakenings of the infant are extinction (standard, with parental presence, and gradual), the bedtime routine, scheduled awakenings, and preventive parental education. Different types of extinction, even if supported from literature, present limits about their application due to the difficulty and will of the parents to continue such actions. The difficulty arises from the fact that the parents cannot ignore their child's cries, above all for a period of time. It has also been suggested that extinguishing (standard) strategies could be detrimental to the mental health of the child and the parent-child attachment [17]. However, literature shows that in about 80 % of children treated with the extinction procedure reported improvements in sleep and the positive responses that show up after several weeks of intervention [9]. Apart from the possible effects of cognitive-behavioral interventions, the parent-child attachment, the infant's sense of security, the long-term efficiency of cognitive-behavioral interventions are other issues that have received little attention. There is substantial evidence that testify the long-term benefits with few exceptions, the most part of the follow-up studies were limited to 6-30 months after the intervention [12,13]. The follow-up analysis would be important for both the child and the family as it could provide a good motivation for applying this type of intervention. Furthermore, it is important to know the long-term consequences of sleep disorder in those who do not receive any treatment in early childhood and would be appropriate to conduct further studies to verify the efficacy of these treatments.

Despite these shortcomings, so far the data (uncontrolled case studies and some well-controlled trials) provides a positive feedback about the effectiveness of behavioral interventions, which should increase the benefits for the patient but should be better defined. The treatment of cognitive - behavioral was more effective than no treatment, placebo, drugs and alternative therapies [37]. The identification and management of sleep disorders in childhood may improve the health and emotional well-being in adolescence and adulthood [15].

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## SUMMARY

### MANAGING SLEEP DISORDERS IN CHILDREN: WHICH IS THE BEST STRATEGY ?

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This review aims to critically analyze the literature studies showing the effectiveness of cognitive-behavioral strategies in the treatment of sleep disorder during the developmental age. About 15-35% of children suffer from sleep disorder. If they are not treated right away, it can persist into adulthood. Recent studies demonstrate an effective cognitive-behavior treatment for these disturbances. In this regard, the most effective method seems to be extinction (standard, with parental presence, graduated), the bedtime routine, scheduled awakenings, and preventive parent education. The procedures of extinction, not only its effectiveness, have limited application for the difficulty that compares to the parents following the procedure of the intervention. They are not able to ignore their children when they are crying for long prolonged period of time. Bedtime routine is relevant in the prevention and treatment of sleep disorders. The scheduled awakenings are a useful technique that teaches parents to change the way they interact with the child's disturbed sleep, allowing recovery. Finally, preventive parental education depends on the parents or caregivers and aims to educate them; during the prenatal or postnatal period with their child's sleep it seems useful

in preventing irregular pattern formation and temporal regulation of sleep.

The vast majority of children's sleep disruptions seem to resolve only with the cognitive-behavioral intervention, while in some psychopathologic disruptions it is necessary to combine cognitive-behavioral and drug therapy.

Literature reviews show that clinical research concerning sleep disruptions is still very limited. In current reviews, there have been diverse investigations on efficacy of cognitive-behavioral interventions and sleep disruptions, highlighting both the strong points and weak points. Therefore, this analysis could be a starting point for developing further research since there is a lack of studies in relation to evidence-based interventions and specific therapeutic factors for each intervention and disturbance.

**Key words:** sleep disorder, cognitive-behavioral treatment, drug therapy, developmental age.



## РЕЗЮМЕ

### УПРАВЛЕНИЕ РАССТРОЙСТВАМИ СНА У ДЕТЕЙ: ЧТО ЯВЛЯЕТСЯ ЛУЧШЕЙ СТРАТЕГИЕЙ?

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Целью обзорной статьи является критический анализ литературы относительно эффективности когнитивно-бихевиористской терапии расстройств сна в период развития ребёнка. Приблизительно 15-35% детей страдают от расстройства сна. Если заболевание не вылечить сразу, то оно может присутствовать и во взрослой жизни. Исследования показали эффективность когнитивно-бихевиористской терапии расстройств сна у детей. В этом отношении, наиболее результативными методами являются экстинкция (стандартная, в присутствии родителей, градуированная), ритуал подготовки ко сну, запланированные пробуждения и профилактическое обучение родителей. Процедуры экстинкции, несмотря на ее эффективность, имеют ограниченное применение ввиду трудностей в осуществлении вмешательств. Родители не в состоянии игнорировать плач своих детей в течение длительного промежутка времени. Ритуал подготовки ко сну важен для предотвращения и лечения расстройств сна. Запланированные пробуждения - полезная техника, которая учит родителей взаимодействовать с нарушением сна ребенка

по-разному и способствует выздоровлению. Успех в профилактическом обучении родителей зависит от самих родителей или опекунов. Обучение направлено на предотвращение формирования нерегулярной модели сна и временное регулирование сна в предродовом или послеродовом периодах.

В большинстве случаев для излечения нарушений сна достаточно когнитивно-бихевиористская терапия детей, только в некоторых случаях психопатологических нарушений требуется комбинированное лечение: когнитивно-бихевиористская терапия и фармакотерапия.

Анализ литературы показал небольшое число клинических исследований по расстройству сна. В обзорах литературы последних лет, посвящённых эффективности когнитивно-бихевиористской терапии при нарушениях сна, освещались сильные и слабые стороны данного метода лечения. Представленный анализ литературы может стать отправной точкой для дальнейших исследований.

## რეზიუმე

ძილის დარღვევების მართვა ბავშვებში: რომელია სწორი სტრატეგია?

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და მოზარდთა ნეირო-ფსიქიატრიის დეპარტამენტი, მედიცინისა  
და ოდონტოლოგიის ფაკულტეტი; <sup>2</sup>მედიცინისა და ფსიქოლოგიის ფაკულტეტი;  
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ბავშვების 15-35%-ს აღენიშნებათ ძილის დარღვევები. თუ მკურნალობა დროულად არ იქნა ჩატარებული, დაავადება შეიძლება მოზრდილობის პერიოდშიც გაგრძელდეს. ბოლო წლების გამოკვლევებმა აჩვენეს

შემეცნებითი-ქცევითი თერაპიის ეფექტურობა ასეთი სახის დარღვევების დროს. ამ მხრივ, ყველაზე ეფექტური მეთოდებია ე.წ. ექსტინქცია (სტანდარტული, მშობლების თანდასწრებით, გრადუირებული), დასაძინებლად



მომზადების რიტუალი, დაგეგმილი გაღვიძება და მშობლების პრევენციული განათლება. სირთულის გამო ექსტინქციის პროცედურები შეზღუდულად გამოიყენება. მშობლებს არ შეუძლიათ ყურადღება არ მიაქციონ ბავშვების ხანგრძლივ ტირილს. დასაძინებლად მომზადების რიტუალი მართებულია ძილის დარღვევების პრევენციისა და მკურნალობისთვის. დაგეგმილი გაღვიძება კარგი მეთოდია, რომლის მეშვეობით მშობლები სწავლობენ, თუ როგორ უნდა მიუდგნენ შვილის ძილის დარღვევების პრობლემას, რაც გამოჯანმრთელებას უწყობს ხელს. და ბოლოს, მშობლების პრევენციული განათლება დამოკიდებულია თვით მშობლებზე ან ძიებზე და მიმართულია არარეგულირებული ძილის მოდელისა და ძილის დროული რეგულაციის გამომუშავების პრევენციაზე პრენატალურ თუ პოსტნატალურ პერიოდებში.

ბავშვებში ძილის დარღვევის უმრავლესი შემთხვევები საჭიროებს მხოლოდ შემეცნებით-ქცევით ჩარევებს, თუმცა ზოგიერთ შემთხვევებში საჭიროა მედიკამენტოზური მკურნალობის დამატებაც.

ლიტერატურული მიმოხილვა გვიჩვენებს, რომ ძილის დარღვევებზე კონცენტრირებული კვლევები საკმაოდ შეზღუდულია. ბოლო წლების მიმოხილვებში წარმოდგენილია სხვადასხვა კვლევა შემეცნებით-ქცევითი ინტერვენციების ეფექტურობაზე ძილის დარღვევების დროს, ნაჩვენებია როგორც ძლიერი, ასევე სუსტი მხარეებიც. ამრიგად, მოცემული ანალიზი შეიძლება ჩაითვალოს საწინდრად შემდგომი კვლევების დაგეგმვისათვის, რადგან მტკიცებულებებზე დაფუძნებული მედიცინის პრინციპების დაცვით შესრულებული კვლევები აღნიშნულ სფეროში საკმაოდ მცირეა.

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## TEMPO AND AMPLITUDE IN GROWTH

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Growth is defined as an increase of size over time with time usually defined as physical time. The human growth curve has a unique pattern with characteristic changes in height velocity [1]. Height velocity is defined as the difference of two height measurements divided by the time interval in between. Rapid intrauterine growth with maximum height velocity in the 3<sup>rd</sup> trimester is followed by a postnatal spurt immediately after birth, a mid-growth spurt at the age of 6-7 years, and a pubertal growth spurt with peak height velocity during mid-puberty, around the age of 13-14 years in boys, and 11-12 years in girls. In addition, minor spurts exist. Cyclic variation in height

velocity at approximately 2 year periodicity has been described by Butler et al. [3], and short-term changes in height velocity occur at even smaller intervals of few days (mini-growth spurts) at intervals of 2 to 10 days, followed by periods of growth arrest or diminished growth velocity [8]. As this pattern consists of jumps followed by stagnation, some authors refer to it as saltation and stasis [Lampl et al. 12]. During periods of illness, starvation or social deprivation, height velocity tends to decelerate, but usually rises again and compensates for the previous losses (catch up growth [22]) when the unfavourable situation has been overcome.

### Plotting growth – the two components

We are used to plot growth measurements on Cartesian coordinate systems with an x-axis and a y-axis. Children grow with age, height depends on age, and we therefore depict height on the y-axis (dependent variable) and age on the x-axis. Yet, the rigid metric of physical time is not directly relevant to the internal dynamics of growth. Growth is linked to maturation. Children who grow also mature. Children and adolescents differ in the tempo at which they mature. In contrast to the metric scale for height (cm) and the metric scale for physical time (age in years) there is no apparent metric scale for maturation. One calendar year differs in its meaning in a fast maturing, and in a slow maturing child. The slow child needs more calendar years for completing the same stage of maturity. This is true also for a population. Different ethnic groups and groups that live under different economic, political or historical circumstances differ in tempo. Figure 1a shows the 50<sup>th</sup> percentiles for height in 5 representative German growth studies; one old and one modern study from 1893 [15] and 1997 [9], one study from post-war West Germany (1956 [21]), and two studies from the former German Democratic Republic (1961 [18]) and (1991 [4]). Except for infancy and childhood, 19<sup>th</sup> century Germans were shortest at all ages and reached final height late. The Figure is done in the usual way, and plots height measurements in centimetres (y-axis) on age in years (x-axis). Let us transpose the x- and the y-axis (Figure 1b), and plot age in years (y-axis) on height in centimetres (x-axis). This plot now depicts age groups that are to be expected in particular height classes. E.g., the 164 cm-height class comprises 14-year old Germans from 1997, but 16-year old ones from 1893. The question rises: are modern adolescents taller, or do they mature at faster pace? Or shall we ask: is modern growth characterized by a larger amplitude component, or by a faster tempo component?

In fact, both is true. But measuring tempo is difficult. In the early 1960ies, Hewitt and Acheson [10,11] introduced a scoring system for measuring maturity as an indicator of tempo. Maturity scores exhibit gender dimorphism, with girls scoring approximately two years earlier than boys. Unfortunately, the scores for skeletal maturity were later turned back into male and female “bone ages”, muddling up mean annual developmental progress of the reference population, “calendar age”, and the individual progress in maturation. This uncomfortable semantic confusion still persists. Significant progress was recently made using

Functional Data Analysis and Principal Component Analysis [17]. Functional Data Analysis provides a statistical tool to separate and differentiate amplitude and developmental progress (tempo). Using Principal Component Analysis it is possible to quantify amplitude and tempo [6]. This approach does not require an external estimate of developmental progress, but utilises information that is already present in longitudinal sets of measurements and can even be used in historical sets of data [13].



Fig 1a. 50<sup>th</sup> percentiles for height in 5 German growth from 1893 [15], 1997 [9], West Germany (1956 [21]), German Democratic Republic (1961 [18]) and 1991 [4]). The Figure is done in the usual way, and plots height in centimetres (y-axis) on age in years (x-axis)

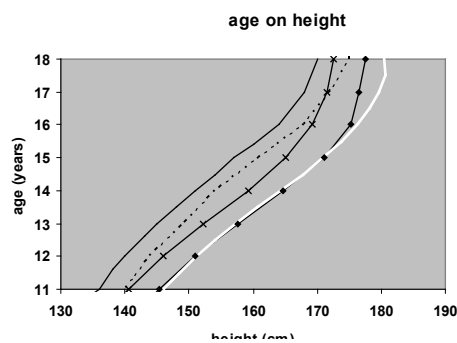


Fig 1b. 50<sup>th</sup> percentiles for height (Figure 1a) after transposing the x- and the y-axis, plotting age (y-axis) on height (x-axis)

Let us redraw the data again, and instead of absolute height, plot percent of final height (y-axis) on age in years (x-axis) (Figure 2a). Differences in amplitude now disappear, and the studies converge at final height (18 years). Transposing the x- and the y-axis (Figure 2b) illustrates that East German adolescents had reached 92% of final height already at 14 years, whereas the 1956 post-war and the late 19<sup>th</sup> century Germans reached 92% not before the age of 15 years, i.e. one year later. Historic Germans matured at a

slower pace and needed one year longer for final height.

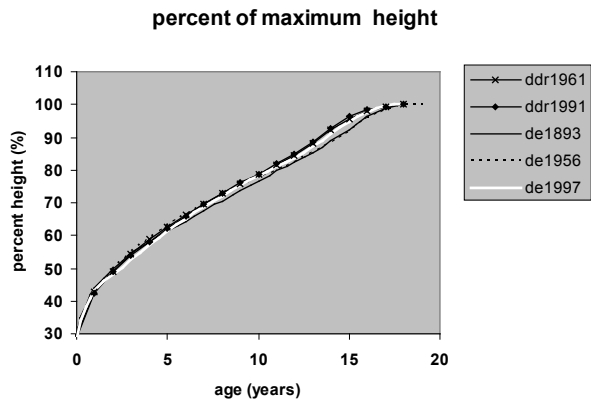


Fig 2b. 50<sup>th</sup> percentiles for height plotting percent of final height (y-axis) on age (x-axis). The studies converge at final height (18 years)

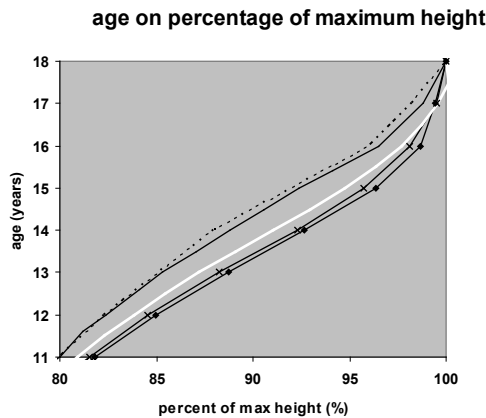


Fig 2b. 50<sup>th</sup> percentiles for height (Figure 2a) after transposing the x- and the y-axis, plotting age (y-axis) on height (x-axis)

**“Catch-up growth” or “catch-up in tempo”**

Many characteristics in the human growth curve are tempo characteristics. *Catch-up* growth after periods of illness and starvation [16] is usually a catch-up in tempo, with little or almost no effect on amplitude. Rich historic evidence illustrates the effects of social disaster on growth, and at the same instant shows, that these effects are almost completely limited to tempo. During the German occupation of World War II, Oslo schoolgirls showed marked growth impairment coinciding with the period of disaster [2], but rapidly caught up and achieved normal adult stature (Figure 3). The growth impairment was simply a delay in tempo, the catch-up thereafter, was a catch-up in tempo. The years of starvation and political depression had no effect on the amplitude component in this population. Similar phenomena were observed in German school boys during and after World War II [5].

Tempo appears to be more sensitive than amplitude to nutrition, health and environmental stress. This also applies for most clinical situation.

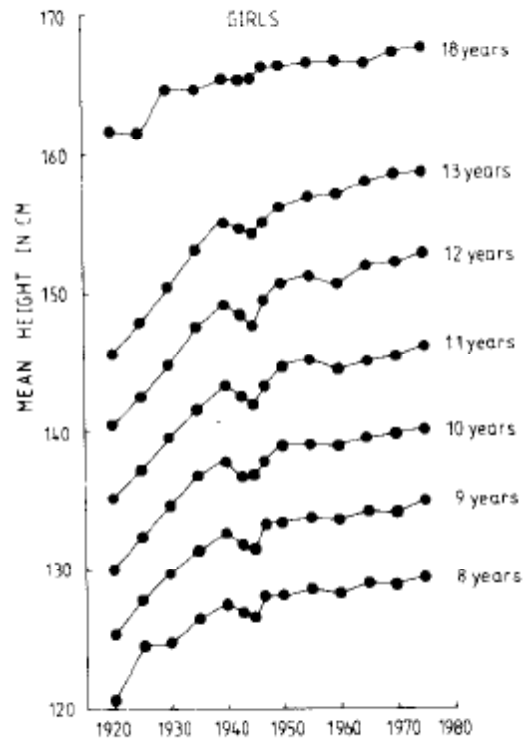


Fig 3. Mean height of Oslo school girls between 1920 and 1975 ([2], reprint by courtesy of the publisher). Marked reduction of height is obvious in cohorts that suffered from starvation during the German occupation of World War II. After starvation, catch up growth occurred immediately with no evidence of persistent growth impairment. Height in 18 year old females (near final height) appeared unaffected by the starvation. The apparent height losses in the 8, 9, and 10 year old cohorts of 1942 have disappeared in the 18 year old cohorts of 1950, 1951 and 1952 (same individuals)

**The clinical situation**

Significant improvements in growth velocity are often taken as medical success when treating growth disorders. But growth velocity is defined by calendar time, and by definition, never refers to tempo. Also in the clinical situation, we need to disentangle amplitude and tempo.

Patients with congenital adrenal hyperplasia (CAH) are accelerated in tempo. Figure 4 illustrates the patterns of height SD scores and tempo advancement (maturation age minus calendar age in years) in a CAH girl with a more than 3 year acceleration in tempo. Tempo is shown by Principal Component Analysis and Maximum Likelihood Principle [6]. The graph

illustrates how closely both height SDS and tempo correspond to each other. The figure underscores also in this case that “growth advancement” expressed in height SDS, is tempo advancement. Figure 5 shows

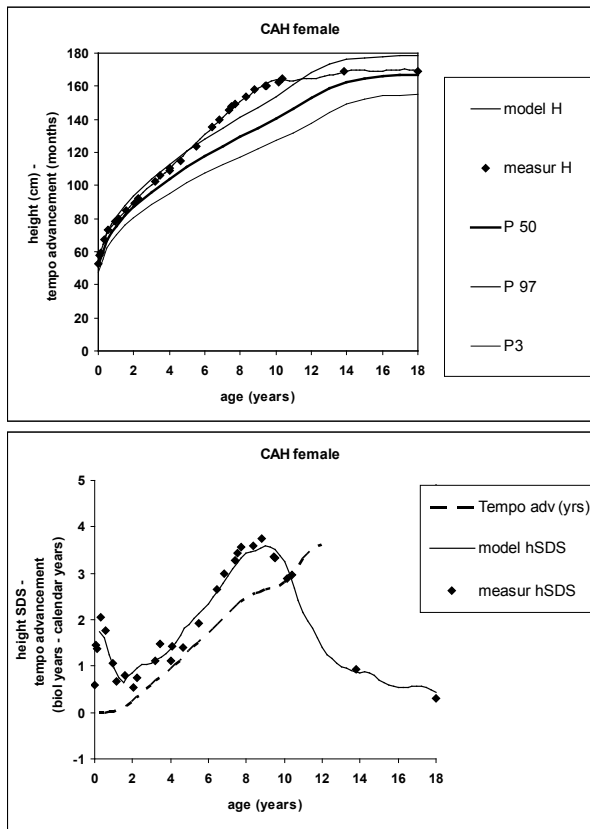


Fig 4. Upper graph: measured height (measur H), modeled height (model H [6]) and three common percentiles (P50, P3 and P97) in a CAH female with advanced developmental tempo. Upward percentile crossing during pre-pubertal age is obvious.

Lower graph: tempo advancement (tempo adv) and height SDS of the same child. The tempo steadily advances over physical time and reaches a plus of more than 3 years at the calendar age of 12. The tempo advancement parallels the increase in height SDS

An appropriate analysis of growth requires disentangling its two major components: amplitude and tempo. The assessment of the developmental tempo thus is an integral part of assessing child and adolescent growth. Apart from assessing skeletal maturity that has recently been automatized [19,20] with surprisingly good results, and plotting serial measures of height SDS and searching for characteristic SDS patterns such as percentile crossings and SDS peaks [7], it is strongly recommended to further analyse growth patterns by applying Principal Component Analysis. Though an Internet portal is currently avail-

a cystic fibrosis patient who decelerated up to 1.6 year in tempo, but reached appropriate final height. The tempo impairment did not impair the amplitude component of growth.

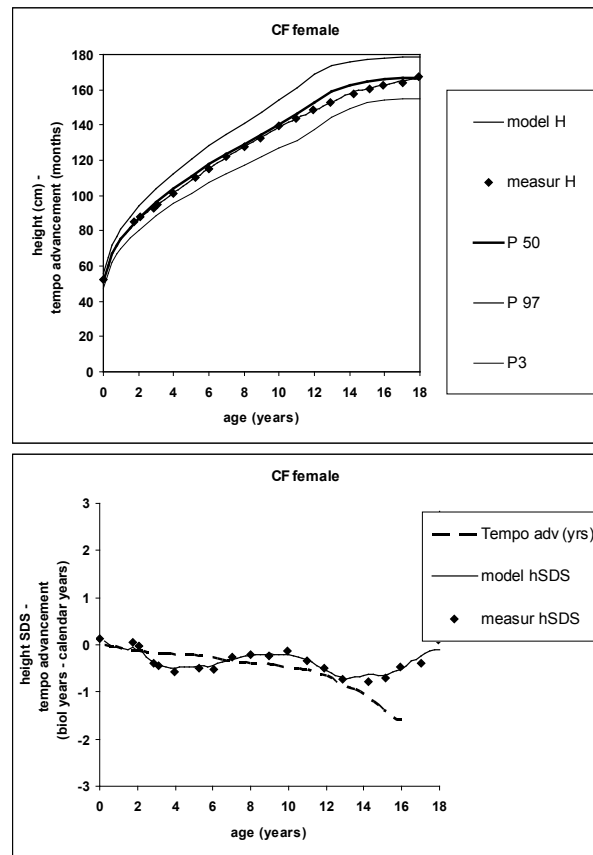


Fig 5. Upper graph: measured height (measur H), modeled height (model H [6]) and three common percentiles (P50, P3 and P97) in a late maturing CF female. Downward percentile crossing is obvious.

Lower graph: tempo advancement (tempo adv) and height SDS of the same child. The tempo steadily declines below physical time and reaches -1.6 years at the calendar age of 16. The tempo retardation nicely parallels the decrease in height SDS

able to process small amounts of height data ([www.willi-will-wachsen.com](http://www.willi-will-wachsen.com)) for separately determining amplitude and tempo in growth [14], there is urgent need of better and practical solutions for analyzing individual growth.

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## SUMMARY

### TEMPO AND AMPLITUDE IN GROWTH

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Growth is defined as an increase of size over time with time usually defined as physical time. Yet, the rigid metric of physical time is not directly relevant to the internal dynamics of growth. Growth is linked to maturation. Children and adolescents differ in the tempo at which they mature. One calendar year differs in its meaning in a fast maturing, and in a slow maturing child. The slow child needs more calendar years for completing the same stage of maturity. Many characteristics in the human growth curve are tempo characteristics. Tempo – being fast or slow maturing – has to be carefully separated from amplitude – being tall or short. Several characteristic phenomena such as catch-up growth after periods of illness and starvation are largely tempo phenomena, and do usually not affect the amplitude component of growth. Applying Functional Data Analysis and Principal Component Analysis, the two main sources of height variance: tempo and amplitude can statistically be separate and quantified. Tempo appears to be more sensitive than amplitude to nutrition, health and environmental stress. An appropriate analysis of growth requires disentangling its two major components: amplitude and tempo. The assessment of the developmental tempo thus is an integral part of assessing child and adolescent growth. Though an Internet portal is currently available to process small amounts of height data ([www.willi-will-wachsen.com](http://www.willi-will-wachsen.com)) for separately determining amplitude and tempo in growth, there is urgent need of better and practical solutions for analyzing individual growth.

**Key words:** amplitude, tempo, height velocity, maturation.



## РЕЗЮМЕ

### ТЕМП И АМПЛИТУДА РОСТА

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Под термином рост понимается изменение размеров тела или уровней зрелости организма ребенка и определяется как увеличение размера тела в течение определенного периода времени. Скорость роста ребёнка связана с созреванием. Однако известно, что созревание детей протекает в разном темпе. Один календарный год отличается по своему значению у детей, созревающих в быстром и у детей созревающих в более медленном темпе. Ребенок, созревающий в медленном темпе, нуждается в большем количестве календарных лет, чтоб достичь стадии зрелости. Темп, означающий быстроту или медленность созревания, необходимо разграничить от амплитуды, означающей быть высоким или низким. Характерная черта темпа роста – возможность наверстать дефицит роста после периода болезни и голодания, не влияет на амплитудный компонент роста. С помощью функционального анализа данных (FDA) и с помощью метода основных компонентов (PCA) можно статистически разграничить и подсчитать два основных источника дисперсии высоты: темп и амплитуду. Темп представляется более чувствительным, чем амплитуда по приему пищи, здоровью и экологическому стрессу. Должный анализ роста требует отдельного рассмотрения этих двух его основных компонентов: амплитуды и темпа. Таким образом, оценка темпа развития является неотъемлемой частью оценки роста ребенка и подростка. Хотя интернет-портал для обработки малых количеств данных роста ([www.willi-will-wachsen.com](http://www.willi-will-wachsen.com)) в настоящее время доступен, для того, чтобы с целью анализа роста отдельного индивидуума отдельно определить амплитуду и темп роста, необходим поиск лучших и практических решений.

## რეზიუმე

ზრდის ტემპი და ამპლიტუდა

მიხაელ ჰერმანუსენი

აშაუგოფი, ალტენჰოფი, გერმანია

ზრდა განისაზღვრება, როგორც სხეულის ზომის მატება გარკვეულ დროში, ანუ როგორც ფიზიკური დრო. თუმცა ფიზიკური დრო არ არის პირდაპირ დამოკიდებულებაში ზრდის შიდა დინამიკასთან. ზრდა დაკავშირებულია მომწიფებასთან. ბავშვები და მოზარდები განსხვავდებიან მომწიფების ტემპით. კალენდარული წელი განსხვავებულია მომწიფების სწრაფი და ნელი ტემპის მქონე ბავშვებში. ბავშვს მომწიფების ნელი ტემპით მეტი კალენდარული წელი სჭირდება მომწიფების გარკვეული დონის მისაღწევად. ადამიანის ზრდის მრუდის ბევრი თავისებურება ტემპის თავისებურებას წარმოადგენს. ზრდის ტემპი ამპლიტუდასთან შედარებით უფრო მგრძობიარე არის ისეთი ფაქტორების მიმართ, როგორიცაა: კვება, ჯანმრთელობის მდგომარეობა, გარემოთი განპირობებული სტრესი. ზრდის შეფასებისათვის საჭიროა მისი ორი ძირითადი კომპონენტის – ამპლიტუდისა და ტემპის - ცალ-ცალკე განხილვა. ამგვარად განვითარების ტემპის შეფასება ბავშვთა და მოზარდთა ზრდის შეფასების განუყოფელ ნაწილს წარმოადგენს. მიუხედავად იმისა, რომ ინტერნეტ პორტალზე [www.willi-will-wachsen.com](http://www.willi-will-wachsen.com) მოცემულია ამჟამად მიღებული მარტივი მეთოდი ზრდის ტემპისა და ამპლიტუდის ცალ-ცალკე გამოთვლისთვის, ინდივიდუალური ზრდის შესაფასებლად უკეთესი და უფრო პრაქტიკული საშუალებების მოძიებაა აუცილებელი.

## ANTHROPOMETRIC DATA PECULIARITIES IN EARLY SCHOOL CHILDREN POPULATION

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Physical development is an objective, integral indicator for children population health assessment, that reflects complex influence of biological, social, economic, hygienic, climate, geographic factors on child organism [2,5].

Children's growth and development is determined by endogenous (parental health, endocrine system pathology, inheritance patterns), and exogenous factors (nutritional status, relaxing, physical and mental load, and etc.). According to published references analysis from decades to decades the variability of children's anthropometric data is under the influence of nutritional conditions [7], urbanization [3], and genetic factors [10]. Observation of 22, 000 school aged children revealed processes of acceleration and deceleration in most of aged groups [9]. Anthropometric study data conducted in similar groups are the basis for population monitoring on the giving territory [4,5].

An appropriate informative method for physical development assessment is to determine the harmonization of biological development level of individual and its morpho-functional status.

During the process of individual physical development data assessment the level of anthropometric measurements are given in percentile intervals [4,8]. On the basis of nonparametric statistical analysis percentile method gives possibility to evaluate child development rate along with ontogenesis and to reveal nutritional disorders in time [1,6].

The aim of study was the assessment of harmonization degree level of anthropometric data and physical development in early school aged children.

The cross-sectional, single study was carried out. After the preliminary identification by the method of simple randomized election of schools and observed persons was performed. Representative population of 400 otherwise healthy early school aged children were included in study group. Study period covered the end of school year.

Criteria to be included in the study were: early school age (6 to 7 years of children); secondary school attendance before the study was started; parental agreement for child assessment.

Criteria to be excluded from the study were: refusal to be included in the study; chronic somatic pathology, which could itself cause nutritional disorders.

In the selected contingent anthropometric measurements (body height, body weight, head and chest circumference) were assessed, and body height and weight percentile table was constructed. For selection characteristics the points of third, tenth, twenty fifth, fifties, seventy fifth, ninetieth, ninety seventh percentiles were used. The dissociation between these percentiles makes the percentile intervals. Those data that were between the range 25-50-75 percentiles were consumed as the normal. Data less than 3 percentile and above 97 percentile presumed as the abnormal. The level of physical development harmonization was evaluated by the use of 2 dimensional percentile table - "body height – body weight".

According to study results the mean height normative data in 6 year-old children (interval IV-V) was characteristic for 14 %. For girls it was 112-118 cm and for boys 113-118 cm. In most of cases there has been revealed the tendency to height increase (40 %). Very high numerals (more than 97 percentile) were in 45 % of cases. Among them for girls it was 125-133 cm, and for boys – 126-140 cm. similar changes observed in 6 years old children in terms of body weight measurements. Only 21 % of children had mean body weight data, and for girls it was 19-22 kg, and for boys – 20-22 kg. In both groups evenly observed the tendency for weight gain. In this group among 28 % of cases data were increased, and in 19 % of cases data were above 97 percentile. For 6 years of age girls very high measurements were 29-40 kg, and for boys – 30-40 kg.

In 7 years old children the mean height normative percentiles (intervals IV-V) were observed in 20 %

of cases and for both, for girls and boys they were 120-125 cm. In most of cases (79 %) in both groups there has been revealed the tendency to height increase. In difference with 6 years old of children group the acceleration degree was less prominent. More than 97 percentile (very high measure) was in 30 % of cases, and for girls it was 133-140 cm and for boys 133-138 cm.

According to percentile data table for body weight in 7 years of age group children there have been observed weight mean data in 23 % of cases. For girls

it was 21-23 kg and for boys 22-23kg. The tendency to weight gain was equal in both subgroups. Weight gain was in 26 % of cases, high measurements - in 26%, body weight gain very high level – in 19%. For 7 years of age girls very high level of weight gain data were 34-38 kg and for boys – 33-42 kg.

In general, anthropometric data in boys were high in comparison with physical development data in girls. But, here it worth to mention, that this differentiation was not statistically proved (table).

Table. Physical development data in coordination with sex in children

Anthropometric data	Statistical significance					
	Mean	Std. Error of Mean	Median	Mode	Std. Deviation	Minimum Maximum
<b>Weight (kg)</b>						
Girls	24.62	0.285	24.00	24	3.918	19;40
boys	25.57	0.320	25.50	22	4.315	16;40
<b>Height (cm)</b>						
Girls	123.67	0.390	123.00	122	5.358	112;135
boys	124.07	0.444	124.00	122	5.986	110;138
<b>Chest circumference (cm)</b>						
Girls	62.81	0.332	63.00	64	4.569	55;76
boys	63.78	0.305	64.00	65	4.117	55;76
<b>Head circumference (cm)</b>						
Girls	51.56	0.120	52.00	52	1.645	45; 55
boys	52.10	0.124	52.00	52	1.679	48; 56

An internal correlative links have been revealed between children’s physical development data. Significant correlative links ( $C=0.716$ ;  $p=0.000$ ) were observed between weight and height numerals. These two parameters themselves have a significant influence on head and chest circumference (weight-height to head circumference  $C=0.574$ ;  $p=0.000$   $C=0.558$ ;  $p=0.000$ . weight-height to chest circumference  $C=0.750$ ;  $p=0.000$ .  $C=0.572$ ;  $p=0.000$ ).

The degree of children’s physical development harmonization was determined according to body weight and height ratio expressing in percentile data. Two dimensional percentile tables - “body height – body weight”. Evaluation was performed by following gradation system: Harmonized physical development – all anthropometric data were situated in the range of 25 and 75 percentiles, and difference between intervals was no more than 1; Disharmonized - body weight and height were less in comparison with to normal data because of weight deficit (percentile 10-25) or were more

than normal in favor of obesity (percentile 75-90) i.e. the difference between intervals was 2; Very disharmonized - during physical development body weight and height were markedly less than normal values (percentile 3-10) or were markedly excessive than normal (percentile 90-97) i.e. the difference between intervals was more than three.

Physical development harmonization values were studied in 200 children. Harmonized physical development revealed in 50 children (25%); disharmonized physical development I 50 children (15%), among them with I degree weight gain were 48 (24%), and with I degree weight deficit were 2 (1%). Markedly disharmonized development had 100 children (50%), among them with II degree weight gain were 98 (49%), and with II degree weight deficit were 2 (1%).

Thus, on the basis of percentile method of assessment, during both processes, individual anthropo-

metric data and general physical development data in children revealed as follows: in early school aged children body height and weight were markedly increased. This event indicated to the prevalence of acceleration, weight gain and in some cases obesity.

According to the children's anthropometric data and assessment by physical development harmonization percentiles tables three groups of children were organized: main, risk group and the group with deviation in physical development.

In main group there were children, whose physical development during body height and weight one linear assessment was in coordination with median, increased or diminished values (interval III-VI) and harmonized ration between these numerals (normal chart interval IV-V). In main group were included 6 years aged 56% of children and 7 years aged 60% of children, whose anthropometric data were in the range of physiological normative. Due to above mentioned these group of children do not require further specific medical observation.

In risk group were included children: - with body height and weight increased or decreased data (intervals VII and II); Disharmonized physical development (normal chart intervals III-VI); - if body weight and height data deviation from normal values with only one interval. In risk group included children were 6 years of old 25% and 7 years of old 21%. This contingent covered "observation" group, that involved individual measurements upon medical observation.

To the group of children with deviation in physical development belonged: - children with very high or very low values of body height and weight (intervals I and VIII); - those cases where body height and weight data were outside of normal chart on two intervals. In the group of deviation in physical development were collected 19 - 19 % of 6 and 7 years of old children. These selected children organized the "diagnostic" group, that in future needs active, additional and thorough investigations.

In summary, the study of early school aged children's physical development gives possibility for risk groups stratification, which in turn itself makes a strong basis for reasonable preventive measurements and stepwise monitoring implementation.

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## SUMMARY

### ANTHROPOMETRIC DATA PECULIARITIES IN EARLY SCHOOL CHILDREN POPULATION

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The anthropometric data were studied in early school aged (6-7 years old) children and the degree of harmo-



nization during physical development was evaluated. Representative population of 400 otherwise healthy early school aged children was included in study group. Study period covered the end of school year. In the selected under observation focused population the level of individual anthropometric data was determined in percentile intervals according its position.

Anthropometric data assessments by using percentile method it was revealed in early school aged (6-7 years of old children) excess in body height and weight in comparison with normal values. This phenomenon indicates the prevalence of acceleration and weight gain. Anthropometric data in boys were increased while comparing with physical development data in girls. This result difference has the tendency to statistically insignificant.

Physical development harmonization values were studied in 200 children. Harmonized physical development revealed in 50 children (25%); disharmonized

physical development I 50 children (15%), among them with I degree weight gain were 48 (24%), and with I degree weight deficit were 2 (1%). Markedly disharmonized development had 100 children (50%), among them with II degree weight gain were 98 (49%), and with II degree weight deficit were 2 (1%).

According to the children's anthropometric data and assessment by physical development harmonization percentiles tables three groups of children were organized: main, risk group and the group with deviation in physical development.

On the basis of resulted data the study of early school age children's physical development gives possibility for risk groups stratification, which in turn itself makes a strong basis for reasonable preventive measurements and stepwise monitoring implementation.

**Key words:** early school age children, anthropometric data assessments, physical development.

## РЕЗЮМЕ

### ОСОБЕННОСТИ АНТРОПОМЕТРИЧЕСКИХ ДАННЫХ В ДЕТСКОЙ ПОПУЛЯЦИИ МЛАДШЕГО ШКОЛЬНОГО ВОЗРАСТА

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Изучены антропометрические показатели детей младшего школьного возраста (6-7 лет). Проведена оценка качества гармоничности физического развития. Репрезентативная популяция состояла из 400 практически здоровых детей младшего школьного возраста. Исследование было проведено в конце учебного года. Уровень индивидуальных антропометрических показателей определяли по месту расположения в центильных интервалах.

На основании оценки антропометрических данных центильным методом у детей младшего школьного возраста выявлено увеличение роста и веса по сравнению со средними показателями. Антропометрические показатели мальчиков были выше, по сравнению с показателями физического развития девочек, однако, полученные данные не были статистически достоверны.

В процессе исследования были также изучены показатели гармоничности физического развития

у 200 детей. Гармоничное физическое развитие отмечалось у 50 (25%) детей, дисгармоничное - у 50 (25%) детей, среди них повышение массы тела I степени - у 48 (24%), а дефицит массы тела I степени - у 2 (1%). Резкое дисгармоничное физическое развитие было зафиксировано у 100 детей (50%), среди них повышение массы тела II степени - у 98 (49%), а дефицит массы тела II степени - у 2 (1%).

На основании оценки у детей антропометрических показателей и качества гармоничности физического развития центильным методом, были выделены три группы: основная, группа риска и группа, имеющая отклонения в физическом развитии.

Изучение показателей физического развития детей дает возможность стратификации групп риска для проведения целенаправленных превентивных мер и планомерного мониторинга.



## რეზიუმე

ანთროპომეტრიული მონაცემების თავისებურებები უმცროსი სასკოლო ასაკის ბავშვთა პოპულაციაში

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შესწავლილ იქნა უმცროსი სასკოლო ასაკის ბავშვთა (6-7 წელი) ანთროპომეტრიული მაჩვენებლები და შეფასდა ფიზიკური განვითარების ჰარმონიულობის ხარისხი. ფორმირებულ იქნა უმცროსი სასკოლო ასაკის პრაქტიკულად ჯანმრთელ ბავშვთა რეპრეზენტატიული პოპულაცია (400 ბავშვი). კვლევის ჩასატარებლად შერჩეულ იქნა სასწავლო წლის დასასრული. საკვლევ პოპულაციაში ინდივიდუალური ანთროპომეტრიული მაჩვენებლის დონე განისაზღვრა ცენტრალურ ინტერვალებში მისი ადგილმდებარების მიხედვით.

ანთროპომეტრიული მაჩვენებლების ცენტრალური მეთოდით შეფასების საფუძველზე, ადრეულ სასკოლო ასაკში (6-7 წელი) დაფიქსირდა სხეულის სიმაღლისა და წონის მატება, საშუალო მაჩვენებლებთან შედარე-

ბით, რაც აქსელერაციისა და ჭარბი წონის პრევალირებაზე მიუთითებს. ვაჟების ანთროპომეტრიული მონაცემები აღემატებოდა გოგონების ფიზიკური განვითარების მაჩვენებლებს; მიღებული განსხვავება ატარებდა სტატისტიკურად არასარწმუნო ხასიათს.

შესწავლილ იქნა 200 ბავშვის ფიზიკური განვითარების ჰარმონიულობის მაჩვენებლები. ჰარმონიული ფიზიკური განვითარება აღენიშნებოდა 50 (25%) ბავშვს; დისჰარმონიული – 50 (25%) ბავშვს, მათ შორის მასის I ხარისხის სიჭარბით – 48 (24%), ხოლო მასის I ხარისხის დეფიციტით - 2 (1%). მკვეთრად დისჰარმონიული განვითარება აღენიშნებოდა – 100 (50%) ბავშვს, მათ შორის მასის II ხარისხის სიჭარბით - 98 (49%), ხოლო მასის II ხარისხის დეფიციტით - 2 (1%).

ბავშვთა ანთროპომეტრიული მაჩვენებლებისა და ფიზიკური განვითარების ჰარმონიულობის ცენტრალური ცხრილებით შეფასების საფუძველზე გამოყოფილი იქნა სამი ჯგუფი: ძირითადი, რისკის ჯგუფი და ფიზიკურ განვითარებაში გადახრების მქონე ჯგუფი. მიღებული შედეგების მიხედვით უმცროსი სასკოლო ასაკის ბავშვთა ფიზიკური განვითარების შესწავლა იძლევა რისკის ჯგუფების სტრატეგიციზირების საშუალებას, რაც თავისთავად მიზანმიმართული პრევენციული ღონისძიებებისა და გეგმაზომიერი მონიტორინგის განხორციელების საფუძველია.

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## EVALUATION OF TREATMENT EFFECTS IN OBESE CHILDREN WITH CO-MORBID MEDICAL OR PSYCHIATRIC CONDITIONS

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Child and adolescent overweight and obesity (i.e., BMI  $\geq$  85<sup>th</sup> percentile for age and gender for overweight and BMI  $\geq$  85<sup>th</sup> percentile for age and gender for obese) [32] has been identified as one of the primary health concerns of the twenty-first century [5]. Given the increasing prevalence rates of over-

weight and obesity in children and youth worldwide [11,25,26] and the clearly established psychological and physical health consequences of the condition [12,35], there is a need to identify effective treatments for overweight youth presenting to clinical practices for weight management. It is generally accepted that

behaviorally-based, multi-component treatments comprised of nutrition education, dietary modification, and physical activity changes are the preferred method for treating overweight children [e.g., 16,37].

The “Traffic Light Diet” program (TLD) [15] is a treatment for overweight children with a large body of empirical support. The TLD involves a structured dietary plan with food categories based on caloric density and includes recommendations to guide participants’ eating patterns. Multiple investigations have found the TLD to be superior to control conditions in randomized controlled trials (RCTs) [18,20-24] and the long-term maintenance of treatment effects has been documented when the TLD is used in combination with behavioral, familial, and exercise components [19]. However, the majority of these lab based studies have excluded the difficult to treat populations such as the severely obese and children with comorbid conditions [27]. Consequently, little is known about the effectiveness of the TLD for these special populations.

The current investigation was designed to examine the success of the TLD for children enrolled in a 10-week weight loss program conducted at a for-profit pediatric weight loss facility. Consistent with recommendations regarding evaluating effectiveness of evidence-based treatments [34], we investigated “for whom” the TLD is most effective by examining treatment effects across children of varying comorbid diagnostic groupings (i.e., those with comorbidities and those without) as well as across children of varying weight status (i.e., *overweight*, BMI $\geq$ 85<sup>th</sup> percentile vs. *severely obese*, BMI $\geq$ 99<sup>th</sup> percentile). Thus, the study advances the broader goals of the evidence based practice in Psychology movement [1] by examining patient characteristics that influence treatment outcome [2,30]. Overall treatment effects of this intervention were identified in this population in a previous study [28]. The current article reports the outcomes among participant subgroups (based on weight and comorbid status) to explore for potentially different effects of the intervention. Because of mixed research regarding treatment effectiveness in participants with comorbid conditions [36], no specific directional hypotheses are offered for comorbidity or weight status on treatment outcome.

#### **Material and methods. Participants**

Inclusion criteria for the clinical trial from which the

present data were gathered included (a) being designated overweight by treatment center staff (i.e., BMI $\geq$ 85<sup>th</sup> percentile), (b) being between the ages of 6 and 18 years, and (c) having at least one parent willing to attend weekly sessions with the child. Exclusion criteria included the presence of mental retardation, pervasive developmental disorder, or other psychopathology that would prevent participation in the group intervention. A total of 51 families were screened for participation. Three families were excluded (2 because of developmental delay; 1 because of not meeting the BMI percentile criterion). Thus, 48 families were eligible for participation and began treatment.

The children meeting inclusion criteria (n=48) self-identified into the following ethnic/racial categories: Caucasian (n=44, 92%), African American (n=2, 4%), Hispanic (n=1, 2%) and Native American (n=1, 2%). Participants included 22 males (46%) and 26 females and were, on average, 11.9 years of age ( $SD=2.8$  years). Parents of 18 participants (37.5%) reported their child as having a past or current medical and/or psychiatric condition. The average standardized BMI ( $zBMI$ ) was 2.1 ( $SD=.4$ ). A total of 34 (71%) children were classified as overweight or obese and 14 children (29%) were severely obese. The majority of families fell within the middle and upper socioeconomic ranges.

#### *Measures*

*Body Mass Index.* Prior to beginning the program, a physical examination was conducted by a pediatrician affiliated with the bariatric clinic. Participants’ heights and weights were collected at the beginning and end of the intervention. Weights were obtained using a digital scale with participants wearing light clothing and no footwear. Height was measured on a wall-mounted stadiometer, with no footwear. BMI standardized ( $zBMI$ ) for mean and standard deviation ( $zBMI = (BMI - SD)/M$ ) was calculated using norms from the Centers for Disease Control and Prevention [32]. According to CDC norms, at risk for overweight is defined as greater than or equal to the 85<sup>th</sup> percentile for BMI. In order to distinguish overweight children from children significantly overweight, we categorized them using terminology recommended by an expert committee; that is, overweight (i.e., BMI $\geq$ 85<sup>th</sup> percentile), obese (i.e., BMI $\geq$ 95<sup>th</sup> percentile), and severely obese (i.e., BMI $\geq$ 99<sup>th</sup> percentile) [4].

Table. Change in BMI, zBmi, Weight, and BMI Percentile Based on Weight Status and Comorbidity Status (means ± SD)

	Overweight and Obese		Severely Obese	
	Completers <sup>a</sup>	ITT <sup>b</sup>	Completers <sup>a</sup>	ITT <sup>b</sup>
BMI (kg/m <sup>2</sup> )	-1.1 (1.1)	- 1.0 (1.1)	- 2.1 (2.1)	- 2.0 (2.0)
zBMI	-.1 (.1)	- .1 (.1)	- .1 (.1)	- .1 (.1)
Weight (kg)	- 2.2 (2.3)	- 1.9 (2.3)	-4.4 (5.9)	-4.2 (5.5)
BMI percentile	-.8 (1.1)	-1.2 (2.5)	-.2 (.2)	-.2 (.2)
	Overweight to Severely Obese without Comorbidity		Comorbidity	
	Completers <sup>a</sup>	ITT <sup>b</sup>	Completers <sup>a</sup>	ITT <sup>b</sup>
BMI (kg/m <sup>2</sup> )	-1.5 (1.7)	-1.4 (1.6)	-1.2 (1.2)	-1.2 (1.2)
zBMI	-.1 (.1)	- .1 (.1)	-.1 (.1)	-.1 (.1)
Weight (kg)	-3.2 (4.2)	-2.8 (4.0)	-2.3 (3.0)	-2.2 (3.0)
BMI percentile	-.9 (1.1)	-1.1 (2.6)	-.6 (.9)	-.5 (.8)

<sup>a</sup>n=41; <sup>b</sup>n=48

**Comorbidity.** Parents were asked to complete a checklist indicating whether their children had any comorbid medical or psychiatric conditions. The comorbidities reported by parents included asthma (n=7), sleep apnea (n=5), hyperinsulinimnia (n=1), attention deficit hyperactivity disorder (n=5), anxiety disorder (n=3), depression (n=3), and conduct disorder (n=1). Several children had multiple comorbidities (n=8).

*Procedures.*

**Treatment Details.** The present study was designed to specifically test the efficacy of the TLD in an applied setting. To accomplish this in a clinical setting, children and their families attended a weekly treatment program for 10 weeks at a bariatric clinic independent of other medical facilities. Group treatment was provided, and each group consisted of approximately seven children and their parent(s). The treatment included weekly classes comprised of a nutrition and exercise component. Additionally, the clinic included an exercise facility to which families had access throughout treatment. The treatment team for this study was multidisciplinary and included a pediatrician, exercise trainers, a dietitian, and masters level behavior therapists. This for-profit clinic required families to self pay approximately \$850 USD for 10 weeks of treatment.

Children and parents were presented with information to assist with lifestyle changes for their family. The TLD provides an educational program for nutrition and a corresponding physical activity program. The behavioral techniques used (e.g., the use of contracts and social reinforcement, stimulus control, pre-planning) [16] were intended to assist parents and children

in adopting healthier lifestyles. Families attended, on average, 80% of weekly sessions (SD=11.86%).

**Nutrition Education.** Consistent with the TLD [15] participants were taught to increase their intake of foods that are low in fat and high in nutrient density (i.e., “green” foods) and to decrease their intake of foods that are high in fat/sugar and low in nutrient density (i.e., “red” foods). Families were also taught to change their food environments by limiting the number of “red” foods and increasing the number of “green” foods in the home (i.e., stimulus control).

**Exercise Education.** Participants were given information regarding exercise that included increasing caloric expenditure. Additionally, physical trainers assisted in the implementation of lifestyle exercise (e.g., family exercise and sports). Participants were encouraged to increase physical activity through an increase in activities of daily living (e.g., taking the stairs, walking to school). Families were provided with an exercise plan tailored to their preferences for use at home, and received one additional 45-minute group training session with the fitness trainers weekly. Families were also taught to reduce sedentary behaviors (e.g., television watching).

**Results and their discussion.** Statistical analyses were performed using SPSS (version 16.0.1; SPSS Inc., Chicago, IL, USA). Initially, t-tests and chi-square were conducted to evaluate differences on baseline characteristics between participants who remained in the study and those who dropped out prior to the end of the 10-week assessment. Next, t-

test analyses were performed to examine the change in zBMI over the 10-week course of treatment. Children who were severely obese (i.e., BMI percentile  $\geq 99.0$ ) were compared to those whose overweight status more closely resembled the children in Epstein's studies ( $< 99^{\text{th}}$  percentile), and children with at least one parent-reported comorbid condition were compared to children without a reported comorbid condition. To follow up these analyses, a 2X2 (Time X Weight Status) repeated measures analysis of variance (ANOVA) test and a 2X2 (Time X Comorbidity) repeated measures ANOVA were conducted to examine for any existing interactions between time and weight status, as well as time and comorbidity, respectively. Models were developed for both completers and intention-to-treat (ITT) using the last observation carried forward (LOCF) method [33] in order to determine any differences for outcomes between these two groups. See Table 1 for a listing of results.

*Initial analyses.* There were no significant differences between completers and non-completers on baseline demographic variables. A total of 41 families (85%) completed baseline and 10 week measurements.

*Outcomes for the severely obese.* Overall, children had a significant reduction in zBMI as indicated by t-test analyses,  $t(40)=6.6, p<.001$ . These results have been discussed in more detail elsewhere [28]. A total of 12 children (29%) were identified as being severely obese. Children who were severely obese significantly reduced their zBMI,  $t(11)=4.0, p<.01$ . Based on this result, we continued to examine possible differences in change in zBMI between children who were severely obese and those who were not by conducting a 2 (time) X 2 (overweight or obese vs. severely obese) ANOVA. Results indicated a nonsignificant time by weight status interaction effect,  $F(1,39)=1.5, ns$  suggesting similar improvements in BMI across weight status groups.

*Outcomes for children with a comorbidity.* A total of 15 children (37%) were identified by parent report as having at least one medical and/or psychiatric comorbidity. Children who had a comorbid condition significantly reduced their zBMI,  $t(14)=3.9, p<0.01$ . We continued to examine possible differences in change in zBMI between children who did not have a comorbid condition and children who did by conducting a 2 (time) X 2 (comorbidity vs. no comorbidity) ANOVA. No statistically significant difference in the decrease in zBMI was found across groups (i.e., those with comorbidities and those without), as indicated by the nonsignificant interaction term,  $F(1,39)=.7, ns$ .

*ITT analyses.* All intent to treat analyses provided the same results as the completers analyses. Specifically, children who were severely obese significantly reduced their zBMI,  $t(13) = 3.8, p < .01$  and demonstrated a nonsignificant time by weight status interaction effect,  $F(1,46) = 1.8, ns$ . Furthermore, children who had a comorbid condition significantly reduced their zBMI,  $t(17) = 3.6, p < 0.01$  and demonstrated a nonsignificant time by group (i.e., those with comorbidities and those without) interaction effect,  $F(1,46) = 1.6, ns$ .

Improving our knowledge about and implementation of the highest standard of treatment for overweight children is essential to tackling the current obesity epidemic [4]. The current study included a sample that more closely resembles children and families who seek treatment in clinical settings rather than samples typically included in randomized controlled trials for obesity treatments. Participants were not excluded based on having a comorbid condition (37%) or being severely obese (BMI  $\geq 99^{\text{th}}$  percentile; 29%). Our findings of similar effects of the TLD for children with comorbidities or with a severely obese designation hold promise for the application of this treatment to children presenting at clinical practices.

All participants in this study experienced a decrease in zBMI ( $-.12 \pm .11$ ). Though modest, the reductions should be considered clinically significant given that a weight reduction as little as 5% has been shown to significantly decrease the likelihood of developing health problems associated with obesity [10]. The average participant lost 4% of their initial body weight, which approaches levels associated with positive health outcomes. Remarkably, this weight loss occurred over the course of only ten weeks. Although long-term follow up is necessary, the best predictor of success in weight management programs is initial weight loss [13]. Successful outcomes from such a time-limited treatment not only points to potential for future weight loss, but also indicates that a modified TLD is capable of being a cost-effective, practical, and acceptable intervention to participants and practitioners.

The improvements were modest though comparable to weight losses reported in other evidence-based treatments for children [36]. Children with comorbidities demonstrated less change in weight ( $\Delta$  zBMI =  $-.10$ ) than those without additional health or psychiatric problems ( $\Delta$  zBMI =  $-.13$ ), even though between-group differences were not statistically significant. Similarly, severely obese children were somewhat



less successful at reducing their weight ( $\Delta$  zBMI = -.08) than overweight/obese children ( $\Delta$  zBMI = -.13). While these results show that children with comorbidities and/or severely obese status can achieve successful weight outcomes, they may benefit from additional support to further increase their weight loss.

Given that populations and settings will undoubtedly differ, clinicians may wonder which, if any, of the intervention elements may be modified. The program presented here used a modification of the TLD that incorporated guidelines for more convenient foods (e.g. packaged/frozen meals) and eating styles (e.g., restaurant eating). Additionally, the physical activity prescribed to participants was tailored to the families' preferences. Children and their families have disparate dietary and lifestyle routines based on their respective regions, cultures, and socioeconomic status (SES). Therefore, it is important to remain consistent in terms of basic principles (e.g., inclusion of stimulus control, reinforcement, contracting) though specific recommendations may be individualized.

Other intervention elements that may differ across locations include the types of care providers and facilities used. The current intervention was provided by a multidisciplinary team, including a pediatrician, exercise trainers, a dietitian, and supervised master's level behavior therapists. Groups were held in an exercise facility with extensive exercise equipment. This was advantageous for promoting physical activity through training, practice, and modeling of specific exercises for the families. Treatments should be provided in locations that are equipped to accomplish these goals, but minor differences may not significantly impact fidelity.

Modifications may be needed for very overweight children, given the trend in this study toward reduced weight loss and the task of having more weight to lose. For example, the length of treatment may be extended in order for children who remain overweight at the end of treatment to reach a healthier weight status. Adding sessions may allow families increased training and opportunities to implement and maintain healthy lifestyle changes. However, this may negatively impact adherence and dissuade some families from seeking treatment given that extending treatment would impose higher levels of inconvenience and cost to families.

Making modifications to the TLD is one approach to addressing issues of reduced weight loss; however, adjunctive treatments may also be promising

in enhancing the outcomes. For example, in the case of severely obese children, additional options for treatment include pharmacotherapy and meal replacement programs. Pharmacotherapy has been demonstrated as an efficacious method of weight reduction and improved health outcomes among severely overweight pediatric patients [6], and combining this approach with behavioral methods is a viable option. Weight management programs using meal replacements have also yielded significant weight loss in overweight adolescents [3]. This form of treatment appears to result in prolonged satiety, which may be effective for reducing caloric intake and promoting weight management.

Although promising, our results reflect only short-term outcomes. Given the lack of information on long-term effectiveness of child weight management programs in clinical settings, it is imperative that more attention be devoted to the long-term impact of treatment for overweight. It is vital that we identify weight management programs with lasting benefits in "real-world" settings.

A multidisciplinary team approach and the availability of exercise equipment have numerous benefits in providing an obesity intervention. However, these factors resulted in increased cost for services to participants. The high cost for treatment may, in part, explain the small number of participants, particularly those from a lower SES, thus, limiting the generalization of our findings to these groups. Correspondingly, 90% of participants were white and were from middle to upper income families. Clearly, these factors are limitations to the current study. Additional research with increased sample sizes and socioeconomic and ethnic diversity is needed.

Many of the criticisms of using evidence-based treatments in applied settings were directly addressed in this study, and findings lend support to the body of literature indicating that treatments developed and evaluated in laboratory settings can produce significant effects in applied settings as well. This study also identified subgroups of children (i.e., those with severe obesity and those with comorbid conditions) who may not experience the amount of weight loss as others. Continued research is needed with these groups of children to determine additional treatment modifications that may better suit their needs.

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## SUMMARY

### EVALUATION OF TREATMENT EFFECTS IN OBESE CHILDREN WITH CO-MORBID MEDICAL OR PSYCHIATRIC CONDITIONS

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The need for effective treatments for pediatric overweight is well known. To evaluate the applicability of an evidence-based treatment in an applied clinic

setting that includes children with severe obesity and comorbid medical or psychiatric conditions.

Forty-eight overweight children and their families were provided an evidence-based intervention at a for-profit clinic. Unlike typical lab-based samples, participants were self-selected and included children who were very overweight and/or had comorbid conditions. Change in standardized BMI was assessed.

Overall, participants demonstrated a significant reduction in standardized BMI,  $t(40)=6.6$ ,  $p<.001$ . Further analyses indicated that participants who were severely obese and children with a comorbidity significantly reduced their zBMI ( $t(11)=4.0$ ,  $p<.01$ ;  $t(14)=3.9$ ,  $p<.01$ , respectively). Children who were severely obese reduced their BMI percentile by .2 ( $SD=.2$ ) and those with a comorbidity reduced their BMI percentile by .6 ( $SD=.9$ ). Nonsignificant interaction effects indicated comparable weight reductions in severely obese and overweight/obese participants,  $F(1,39)=1.49$ ,  $ns$ . Also, those with comorbidities and those without comorbidities experienced similar weight reductions,  $F(1,39)=.7$ ,  $ns$ .

This study provides promising evidence for the applicability of an evidence-based treatment for weight management in clinical practice.

**Key words:** childhood obesity, evidence-based practice, applied setting, traffic light diet, severely obese, medical and psychiatric comorbidities.

## РЕЗЮМЕ

### ОЦЕНКА ЭФФЕКТИВНОСТИ ЛЕЧЕНИЯ ТУЧНЫХ ДЕТЕЙ С СОПУТСТВУЮЩИМИ ЗАБОЛЕВАНИЯМИ И ПСИХИЧЕСКИМИ НАРУШЕНИЯМИ

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Потребность в эффективном лечении детей с избыточной массой тела хорошо известна. Цель исследования - оценить успешность основанного на доказательствах лечения детей с тяжелым ожирением, сопутствующими заболеваниями и

психическими нарушениями в соответствующих клинических учреждениях. 48 тучным детям и их семьям оказывалось основанное на доказательствах лечебное вмешательство в коммерческой клинике. В отличие от типичных методов отбора, участники были самоотобраны и включали детей с выраженным ожирением и/или имеющими сопутствующие состояния. Определялись изменения в стандартизированном ВМІ. В целом, участники демонстрировали существенное сокращение стандартизированного ВМІ -  $t(40) = 6.6, p < .001$ . Дальнейший анализ выявил, что у участников, которые были чрезмерно тучны и имели сопутствующую патологию, ВМІ значительно уменьшался [ $t(11) = 4.0, p < .01$ ;  $t(14) = 3.9, p < .01$ , соответственно]. У детей, которые были чрезмерно тучны, перцентиль ВМІ уменьшался на .2 ( $SD = .2$ ), а у детей с сопутствующей патологией - на .6 ( $SD = .9$ ). Несущественные эффекты взаимодействия указали на сопоставимое уменьшение веса у чрезмерно тучных и тучных участников,  $F(1,39) = 1.49, не существенно$ . У детей с сопутствующей патологией и без нее имело место сопоставимое снижение веса -  $F(1,39) = .7, не существенно$ . Это исследование предоставляет многообещающее свидетельство применимости основанного на доказательствах лечения для управления веса в клинической практике.

### რეზიუმე

მკურნალობის ეფექტურობის შეფასება მსუქან ბავშვებში თანმხლები დაავადებებისა და ფსიქიკური დარღვევების დროს

კრეიგ ა. ჯონსტონი, ჯინი ფალერტონი, ჯენეტ პოლჩიკ მორენო, შერმენ ტაილერი, ჯონ პ. ფორეტი

ბეილორის სამედიცინო კოლეჯი, ბავშვთა კვების კვლევითი ცენტრი, პიუსტონი, ტეხასი, აშშ

პედიატრიაში სხეულის ჭარბი მასის ეფექტური მკურნალობის საჭიროება კარგად არის

ცნობილი. კვლევის მიზანს წარმოადგენდა შესაბამის კლინიკურ დაწესებულებებში სამედიცინო მტკიცებულებებზე დამყარებული მკურნალობის ეფექტურობის დადგენა მსუქან ბავშვებში თანდართული დაავადებებისა და ფსიქიკური დარღვევების დროს.

ჭარბი მასის მქონე 48 ბავშვსა და მათი ოჯახის წევრებს ჩატარდა მტკიცებულებებზე დამყარებული სამკურნალო ჩარევები სპეციალურ კომერციულ კლინიკაში. ავადმყოფთა შერჩევის ტიპური მეთოდებისგან განსხვავებით კვლევაში ჩართვა თვითშერჩევის ხასიათს ატარებდა, მკურნალობა უტარდებოდა ბავშვებს, რომლებსაც აღენიშნებოდათ გამოსატული სიმსუქნე და/ან თანდართული პათოლოგია. განისაზღვრებოდა სტანდარტიზირებული სხეულის მასის ინდექსის (სმი) ცვლილებები.

ყველა შემთხვევაში მონაწილეებს აღენიშნათ სტანდარტული სმი-ის მნიშვნელოვანი შემცირება -  $t(40) = 6.6, p < .001$ . შემდგომმა ანალიზმა გამოავლინა, რომ ბავშვებს მკვეთრად გამოსატული სიმსუქნით და თანმხლები პათოლოგიით სმი მნიშვნელოვნად შემცირდათ [ $t(11) = 4.0, p < .01$ ;  $t(14) = 3.9, p < .01$  შესაბამისად]. ბავშვებში გამოსატული სიმსუქნით სმი პერცენტილი შემცირდა .2 ( $SD = .2$ )-ით, თანმხლები პათოლოგიის დროს - .6 ( $SD = .9$ )-ით. ჭარბი მასის სხვადასხვა ვარიანტის დროს სხეულის მასის კლება დაახლოებით თანაბრად იყო გამოსატული -  $F(1,39) = 1.49, არასარწმუნო$ . ასევე ბავშვებში თანმხლები პათოლოგიით და მის გარეშე სხეულის მასის კლება დაახლოებით თანაბრად იყო გამოსატული -  $F(1,39) = .7, არასარწმუნო$ .

წარმოდგენილი კვლევა კლინიკურ პრაქტიკაში წონის დასაკლებად მიმართული მტკიცებულებებზე დაფუძნებული მკურნალობის გამოყენებისთვის იმედის მომცემ ინფორმაციას იძლევა.



## ЧТО ПРОИСХОДИТ ПРИ ПЕРОРАЛЬНОМ ПРИЕМЕ БАКТЕРИОФАГА РЕБЕНКОМ?

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Бактериофаги более 100 лет используются в лечении ран и различных инфекций. Начиная с 1898 года, бактериофаги активно исследовались учёными дореволюционной России. В 1930-е годы почётный профессор факультета естественных наук Тифлиского государственного университета Феликс д'Эрелль (d'Herelle), посвятивший свою жизнь экспериментальной медицине, издал в Тифлисе книгу «Бактериофаг и феномен выздоровления», резюмирующую двадцать лет исканий новых путей в медицине [4]. Однако, разработка антибиотиков и внедрение их в клиническую практику снизило интерес к бактериофаготерапии. С открытием антибиотиков в 1940-е годы, везде, кроме СССР, разработки бактериофагов были вычеркнуты из числа перспективных исследований. Однако, в 1980-е годы эффективность лечения антибиотиками значительно понизилась. Серьезные проблемы стали возникать ввиду резкого учащения антибиотикорезистентных штаммов бактерий, аллергических и токсических побочных реакций, дороговизны современных антибиотиков. Всё это обусловило обращение к возможностям терапевтического использования бактериофагов – специфических вирусов, которые атакуют только бактерии и убивают патогенные микроорганизмы [10]. На протяжении последних нескольких лет исследования свойств бактериофагов

проводятся в России, Грузии, Польше, Франции, Германии, Финляндии, Канаде, США, Великобритании, Мексике, Израиле, Индии, Австралии. В начале 2000-х годов Гленн Моррис – сотрудник Университета Мэриленд (США) совместно с исследователями НИИ бактериофагов, микробиологии и вирусологии в Тбилиси наладил испытания фаговых препаратов для получения лицензии на их применение в США. В июле 2007 года бактериофаги были одобрены для использования в США.

В большом количестве исследований, посвящённых биологии фагов и их взаимодействию с бактериями, ввиду их малочисленности, затерялись исследования по распределению фагов в организме, а также иммунной реакции на их прием, в особенности в педиатрической практике [1-17].

Целью исследования явилось изучение распределения назначенных фагов в организме ребенка, а также реакция иммунной системы на лечение.

**Материал и методы.** Под наблюдением находилось 102 ребенка в возрасте от 5 дней до 15 лет, с различными заболеваниями бактериальной этиологии. Данные, характеризующие пациентов, представлены в таблице 1.

Таблица 1. Демографическая характеристика исследованных больных

Возраст	До одного месяца	39
	С одного месяца до одного года	19
	С одного года до 15 лет	44
Пол	♂	52
	♀	50
Диагноз	Пневмония	14
	Сепсис	53
	Мочевая инфекция	9
	Фарингит/синусит	13
	Кишечная инфекция	14

У всех больных проводили бактериологические исследования общепринятыми методами, а также изучали чувствительность к различным антибиотикам. В случаях пневмонии исследовались

мокрота и/или мазок из горла, фарингита/синусита – мазок из горла, сепсиса – кровь, мочевой инфекции – моча, кишечной инфекции – кал. В комплекс лечения включали пиобактериофаг

(многокомпонентный комбинированный препарат, содержащий в себе различные разновидности фагов; препарат выпускается Институтом бактериофага, микробиологии и вирусологии им. Г. Элиава). Пиобактериофаг назначался перорально. Наряду с клиническим мониторингом на 3-5ый день с начала фаготерапии брались пробы (кровь, кал, моча) для определения в них специфических компонентов пиобактериофага. Определение данных компонентов осуществлялось согласно общепринятой методике. Через две недели после начала фаготерапии в сыворотке крови определяли антитела к фагам, используя методику реакции нейтрализации [9,10].

**Результаты и их обсуждение.** У исследованных больных были выделены различные этиологически значимые бактериальные штаммы (всего 69): Staphylococcus aureus - 21, Streptococcus – 21, патогенная E.coli- 23, Pseudomonas aeruginosa- 2, Proteus - 3. Выделенные штаммы были изучены в отношении резистентности к антибиотикам. Резистентность к использованным антибиотикам была следующей – Kanamycin, Streptomycin, Erythromycin/Sumamed, Roxcitan/Roxcibel, Levomycitin, Macropen,

Azthromycin – 99,5-97%; Penicillin, Amoxicillin, Ampicillin, Ampiox, Tetracycline, Cephazoline, Cephalexin, Claforan/Enpoxin, Gentamicin, Amikacin/Zamikan, Doxacyclin - 50-70%; Metacyclin, Ciprofloxacin/Ciprinol, Rocepin/Sepamed, Rifampicin, Clindamycin – 30-40%; Floxan, Avelox – 10-20%. Полученные данные согласуются с таковыми в публикациях, указывающих на учащение бактериальной резистентности к антибиотикам [10,11].

Результаты клинических наблюдений в данной статье не отражены, хотя следует отметить, что во всех случаях наблюдалось улучшение клинического течения болезни (по сравнению с контролем), и отсутствие побочных реакций, связанных с пиобактериофагом.

Пробы крови на наличие в них пиобактериофага были исследованы в 7 случаях, в 6 случаях в крови был обнаружен тот или иной компонент препарата, титры варьировали в пределах от 103 до 104 pfu/ml.

В пробах мочи, взятых у 55 больных, тот или иной компонент препарата был обнаружен у 48, титры варьировали в пределах от 103 до 105 pfu/ml (таблица 2).

Таблица 2. Компоненты пиобактериофага, обнаруженные в моче

Фаги	#1- Pseudomonas aeruginosa	#2 – E. coli	#3 – Proteus vulgaris	#4 – Staphylococcus	#5 – streptococcus	Всего
Частота	34/55	41/55	34/55	31/55	8/56	48/55
	61.8%	74.5%	61.8%	56.4%	14.8%	87.3%

В пробах кала, взятых у 75 больных, тот или иной компонент препарата был обнаружен у 64, титры варьировали от 103 до 104 pfu/ml (таблица 3).

Таблица 3. Компоненты пиобактериофага, обнаруженные в кале

Фаги	#1- Pseudomonas aeruginosa	#2 – E. coli	#3 – Proteus vulgaris	#4 – Staphylococcus	#5 – streptococcus	Всего
Частота	54/75	45/75	37/75	22/75	7/75	64/75
	72.0%	60.0%	49.3%	29.3%	9.3%	85.3%

Следует отметить, что у 11 пациентов, не получавших пиобактериофаг, в моче и кале компоненты пиобактериофага не были обнаружены. Возрастные особенности интенсивности и специфичности обнаружения различных компонентов пиобактериофага в крови, моче и кале не были выявлены.

Полученные результаты на данном этапе не позволяют судить о том, какие факторы обуславливают проникновение того или иного компонента комбинированного

мультифагового препарата (в данном случае пиобактериофага) во внутреннюю среду организма.

Основным результатом проведенных исследований является выявление того факта, что перорально принятый фаг помимо желудочно-кишечного тракта может проникнуть в кровь и мочу. Выявление фага в желудочно-кишечном тракте подтверждает целесообразность применения фаготерапии при кишечных инфекциях. Что касается выявления

фагов в крови и моче при их пероральном приеме, этот факт имеет феноменологический характер. Он указывает на то, что принятый перорально фаг, по крайней мере у детей, способен проникнуть во внутреннюю среду организма. Само собой разумеется, определение количественных соотношений требуют последующих углубленных исследований. Тем не менее, выявленная закономерность может

служить обоснованием для использования пероральной бактериофаготерапии в лечении системных заболеваний, а также инфекций мочевого тракта.

Сыворотка крови на наличие специфических антифаговых антител была исследована у 31 пациента, у 14 были обнаружены антитела, нейтрализующие от 52,5 до 97,3% фаговой активности (таблица 4).

Таблица 4. Частота образования антител к различным компонентам полибактериофага

Антитела к фагам	#1- к <i>Pseudomonas aeruginosa</i>	#2 – к <i>E. coli</i>	#3 – к <i>Proteus vulgaris</i>	#4 – к <i>Staphylococcus</i>	#5 – к <i>streptococcus</i>	Всего
Частота	7/31	9/31	7/31	8/31	6/31	14/31
	22.6%	29.0%	22.6%	25.8%	19.4%	45.2%

Обнаружена выраженная возрастная особенность – у детей раннего возраста антитела или вовсе не определялись, а если определялись, то с низкой активностью. Так например, у детей до 1 месяца антитела были выявлены у 3 из 16, у детей с 1 месяца до года – у 2 из 4, у детей старше одного года – у 9 из 11. Антифаговые антитела могут в определенной мере снижать эффективность фаготерапии. Отсутствие или низкий титр антител у новорожденных, а также у детей в возрасте до года, по всей вероятности, можно объяснить физиологическим недостаточным созреванием иммунной системы; данное обстоятельство предполагает большую эффективность фаготерапии в этих возрастных группах.

Результаты исследования показали, что при пероральном приеме полибактериофага детьми с различными инфекциями компоненты препарата обнаруживаются в крови, моче и кале. При пероральном приеме полибактериофага у части детей обнаруживаются нейтрализующие антитела в сыворотке крови. Антителогенез имеет выраженный возрастзависимый характер – у новорожденных и детей в возрасте до года они практически не обнаруживаются.

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## SUMMARY

### WHAT HAPPENS WHEN THE CHILD GETS BACTERIOPHAGE PER OS?

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The aim of the work was to define the distribution of phages administered per os to children for medical reasons, and the immune response. 102 children aged from 5 days to 15 years with different diseases of bacterial etiology (pneumonia, sepsis, urinary infection, pharyngitis/sinusitis, enteral infection) were monitored. Pyobacteriophage was being included into the complex therapy. The drug was administered per os. In 6/7 of blood, 48/55 urine and 64/75 stool samples taken on the 3-5th day of treatment different components of pyobacteriophage were revealed. The titers varied from 10<sup>3</sup> to 10<sup>5</sup> pfu/ml. No age differences were seen. In two weeks after the onset of the phagotherapy the antibodies to phages were tested in the blood serum using the neutralization reaction method. The blood samples were taken from 31 patients. In 14 of them the antibodies neutralizing 52.5-97.3% of the phage activity were seen. A significant age-related peculiarity was determined: in newborns and infants the antibodies were not revealed or their activity was low.

Obtained results confirm the reasonability to use of peroral phagotherapy in gastro-intestinal infections. At the same time it was ascertained that the phages taken per os can permeate into the internal environment of the organism and thus the peroral phagotherapy can be used to treat systemic infections and urinary tract infections as well. Absence or low production of the antiphage antibodies in newborns and infants suggests high efficacy of the phagotherapy in this age group.

**Key words:** Bacteriophage, distribution in the organism, antiphage antibodies in children.

## РЕЗЮМЕ

### ЧТО ПРОИСХОДИТ ПРИ ПЕРОРАЛЬНОМ ПРИЕМЕ БАКТЕРИОФАГА РЕБЕНКОМ?

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Целью работы явилось изучение распределения, назначенных в лечебных целях, фагов в организме ребенка, а также ответа иммунной системы. Под наблюдением находилось 102 ребенка в возрасте от 5 дней до 15 лет, с различными заболеваниями установленной бактериальной этиологии (пневмония, сепсис, мочевиная инфекция, фарингит/синусит, кишечная инфекция). В комплексную терапию включался пиобактериофаг. Препарат назначался перорально. Взятых на 3-5 дни лечения в пробах крови (7), мочи (55) и кала (75) соответственно в 6, 48 и 64 случаях были обнаружены различные компоненты пиобактериофага; титры варьировали от 10<sup>3</sup> до 10<sup>5</sup> pfu/ml. Возрастные особенности выявлены не были. Через две недели после начала фаготерапии в сыворотке крови определяли антитела к фагам, используя методику реакции нейтрализации. Сыворотка крови на наличие специфических антифаговых антител была исследована у 31 пациента, у 14 были обнаружены антитела, нейтрализующие от 52,5 до 97,3% фаговой активности. Была установлена выраженная возрастная особенность – у новорожденных и детей в возрасте до года антитела или вовсе не определялись, а если определялись, то с низкой активностью. Полученные результаты подтверждают целесообразность применения пероральной фаготерапии при кишечных инфекциях. Установлено, что перорально принятые фаги могут проникать во внутреннюю среду организма и, следовательно, пероральная фаготерапия может быть применена при лечении системных инфекций и инфекций мочевого тракта. Отсутствие или низкая продукция антифаговых антител у новорожденных и детей в возрасте до года предполагает большую эффективность фаготерапии в данной возрастной группе.



## რეზიუმე

რა ხდება, როცა ბავშვი პერორალურად დე-ბულობს ბაქტერიოფაგს?

ყ. ფაღავა<sup>1</sup>, ქ.გაჩეჩილაძე<sup>2</sup>, ი. კორინთელი<sup>1</sup>, მ. ძულიაშვილი<sup>2</sup>, ზ. ალავეიძე<sup>2</sup>, ნ. სოულე<sup>2</sup>, გ. მეცხვარიშვილი<sup>1</sup>

<sup>1</sup>თბილისის სახელმწიფო სამედიცინო უნივერსიტეტი; <sup>2</sup>გ. ელიაშვილის სახელობის ბაქტერიოფაგის, მიკრობიოლოგიისა და ვირუსოლოგიის ინსტიტუტი, თბილისი, საქართველო

შრომის მიზანი იყო პერორალურად დანიშნული ბაქტერიო-ფაგების ორგანიზმში განაწილებისა და იმუნური რეაქციის შესწავლა. დაკვირვების ქვეშ იმყოფებოდა 5 დღიდან 15 წლამდე ასაკის 102 ბავშვი სხვადასხვა ბაქტერიული ბუნების დაავადებით (პნევმონია, სეფსისი, საშარდე გზების ინფექცია, ტონზილიტი/სინუსიტის, ნაწლავური ინფექცია). კომპლექსურ თერაპიაში ირთებოდა პერ-ორალურად დანიშნული პიობაქტერიოფაგი. მკურნალობის მესამე-მეხუთე დღეს სისხლის, შარდისა და განავლის სინჯებში შესაბამისად 6/7, 48/55 და 64/75 შემთხვევაში დადგენილი იქნა პიობაქტერიოფაგის ესა თუ ის კომ-

პონენტი, ტიტრები მერყეობდა 10<sup>3</sup> და 10<sup>5</sup> პფუ/მლ შორის. ასაკობრივი თავისებურებები არ გამოვლენილა. ფაგო-თერაპიის დაწყებიდან 2 კვირაში სისხლის შრატში ნეიტრალიზაციის რეაქციის მეთოდით ისაზღვრებოდა ანტიფაგური ანტისხეულები. 31 პაციენტიდან 14-ში გამოვლინდა ანტისხეულები, რომლებიც ფაგურ აქტივობას 52.5-97.3%-ით ანეიტრალეხს. დადგენილ იქნა მკაფიოდ გამოხატული ასაკობრივი თავისებურება – ახალშობილებსა და ჩვილებში ანტისხეულები ან არ განისაზღვრებოდა ან განისაზღვრებოდა ფრიად დაბალი ტიტრით.

მიღებული შედეგები ადასტურებს პერ-ორალური ფაგოთერაპიის დანიშნის მიზანშეწონილობას ნაწლავური ინფექციების დროს. ამავე დროს ნაჩვენებია, რომ პერ-ორალურად მიღებულ ფაგებს შეუძლიათ შეაღწიონ ორგანიზმის შინაგან გარემოში, რაც მიუთითებს პერორალური ფაგო-თერაპიის გამოყენების შესაძლებლობაზე სისტემური და, ასევე, საშარდე ინფექციების დროს. ახალშობილებსა და ჩვილებში ანტი-ფაგური ანტისხეულების სინთეზის დაბალი დონე გვაძლევს უფლებას ამ ასაკის ბავშვებში ფაგოთერაპიის შედარებით მაღალი ეფექტურობა ვივარაუდოთ.

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