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NUTRITIVNE INTERVENCIJE I KOGNITIVNI ISHODI KOD DECE OD DRUGE DO ŠESTE GODINE ŽIVOTA

Ivana Stepanović[1], Jovana Radovanović[2]
[1]Specijalna bolnica „Dr Žutić“ Beograd, Srbija
[2]Univerzitet u Kragujevcu, Fakultet medicinskih nauka, Katedra za fiziologiju Kragujevac, Srbija

Autor za korespondenciju: Ivana Stepanovic, Specijalna bolnica „Dr Žutić“, Bulevar Zorana Đinđića 125g, 11070 Beograd, Srbija; e-mail: stepanovici69@gmail.com

SAŽETAK
Razvoj kognitivnih sposobnosti dece uzrasta od 2 do 6 godina u značajnoj meri zavisi od nutritivnog statusa. Ovo istraživanje ispituje efikasnost nutritivnih intervencija u odnosu na biološke, socijalne i obrazovne faktore. Prenatalna suplementacija i viši nivo obrazovanja majki povezuju se sa povoljnijim kognitivnim ishodima, dok deca rođena sa niskom porođajnom težinom pokazuju dugotrajnija kašnjenja u kognitivnom razvoju. Efikasnost intervencija varira. Multinutrijentne suplementacije sa pet ili više hranljivih materija pokazuju širi uticaj na kognitivne funkcije u poređenju sa ciljanim suplementacijama. Posebno značajan period za primenu ovog programa predstavlja uzrast između 6. i 18. meseca života. Integracija nutritivne podrške sa obrazovnim pristupima koji uključuju strukturisanu igru i fizičku aktivnost može podstaći paralelan razvoj motoričkih i kognitivnih veština. Metodološki izazovi uključuju potrebu za sprovođenjem randomizovanih kontrolisanih studija, dužim periodima praćenja i korišćenjem laboratorijskih biomarkera za procenu statusa nutrijenata. Rezultati ukazuju na to da efekti intervencija zavise od početnog nutritivnog i zdravstvenog stanja deteta, trajanja tretmana i socijalnog konteksta. Preporuke za buduća istraživanja uključuju proširenje obuhvata na ruralne populacije i decu sa posebnim potrebama, standardizaciju mernih metoda i dugoročno praćenje radi procene održivosti postignutih koristi. Ovakav integralni pristup naglašava važnost koordinacije između zdravstvenih i obrazovnih sektora u cilju unapređenja kognitivnog razvoja.

Ključne reči: kognicija, predškolski uzrast, ishrana

Uvod

Razvoj kognitivnih sposobnosti dece uzrasta od 2 do 6 godina u značajnoj meri zavisi od nutritivnog statusa, što čini nutritivne intervencije posebno relevantnim poljem istraživanja. Efikasnost ovih intervencija zavisi od kombinacije bioloških, socijalnih i obrazovnih faktora. Postoje dokazi da suplementacija mikronutrijentima tokom trudnoće može imati dugoročne efekte na razvoj deteta, smanjujući verovatnoću razvoja suboptimalne razvojne putanje. Viši stepen obrazovanja majki se povezuje sa boljim nutritivnim statusom i kvalitetnijim okruženjem za odrastanje, čime doprinosi povoljnijem kognitivnom razvoju. Kod dece koja su rođena sa niskom porođajnom težinom ili intrauterinim zastojem u rastu zapaženo je dugotrajno zaostajanje u kognitivnim performansama. Neke analize ukazuju da se razlika između ovih grupa i dece sa normalnom porođajnom težinom povećava sa godinama, što potencijalno ukazuje na potrebu za ranom nutritivnom intervencijom kako bi se ublažile dugoročne posledice (1). Sa druge strane, ograničen period praćenja u nekim studijama otežava procenu održivosti efekata interventnih programa na duži rok, zbog čega se sugeriše sprovođenje intervencija koje traju od najmanje tri meseca, uz obuhvat većeg uzorka ispitanika radi preciznijeg zaključivanja.

Neke istraživačke grupe ispitivale su efekte specifičnih prehrambenih proizvoda, bogatih mikro- i makronutrijentima, na decu sa rizikom od zastaja u rastu. Takvi rezultati naglašavaju kompleksnost problema i sugerišu da suplementacija mora biti deo šireg seta intervencija koji uključuje i socioekonomske komponente (2). Pored direktnih efekata mikronutrijenata, kao što su gvožđe, jod ili vitamin D, na neurološki razvoj, sve veće interesovanje usmereno je na masne kiseline koje učestvuju u procesima neuronske komunikacije i mogu imati pozitivan uticaj na brzinu obrade informacija kod dece (3). Intervencije koje kombinuju nutritivnu komponentu sa obrazovnim pristupima, poput programa Head Start REDI i Preschool PATHS, pokazuju određene efekte na so-

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NUTRITIONAL INTERVENTIONS AND COGNITIVE OUTCOMES IN CHILDREN FROM TWO TO SIX YEARS OF LIFE

Ivana Stepanović[1], Jovana Radovanović[2]
[1]Special Hospital "Dr. Žutić," Belgrade, Serbia
[2]University of Kragujevac, Faculty of Medical Sciences, Department of Physiology, Kragujevac, Serbia

Corresponding author: Ivana Stepanović, Special Hospital "Dr. Žutić", Bulevar Zorana Đinđića 125g, 11070 Belgrade, Serbia; e-mail: stepanovici69@gmail.com

SUMMARY
The development of cognitive abilities in children aged 2 to 6 years is significantly influenced by nutritional status. This research examines the effectiveness of nutritional interventions that depend on biological, social, and educational factors. Prenatal supplementation and higher maternal education are associated with more favorable cognitive outcomes, while children born with low birth weight show longer-lasting delays. The effectiveness of interventions varies. Multinutrient supplementation with five or more nutrients demonstrates a broader impact on cognitive functions compared to targeted supplementation. The period between 6 and 18 months of age is particularly important for the implementation of intervention programs. Integrating nutritional support with educational approaches that include structured play and physical activity can promote the parallel development of motor and cognitive skills. Methodological challenges include the need for randomized controlled trials, longer follow-up periods, and the use of laboratory biomarkers to assess nutrient status. Results indicate that the effects of interventions depend on the initial nutritional and health status of the child, the duration of treatment, and the social context. Recommendations for future work include expanding research to rural populations and children with special needs, standardizing measurement methods, and conducting long-term monitoring to assess the sustainability of benefits. This holistic approach emphasizes the importance of coordination between the health and education sectors to enhance cognitive development.

Keywords: cognition, preschool age, nutrition

Introduction

The development of cognitive abilities of children aged 2 to 6 years is significantly influenced by nutritional status, which makes nutritional interventions a particularly relevant field of research. The effectiveness of these interventions depends on the combination of biological, social and educational factors. There is evidence that micronutrient supplementation during pregnancy can have long-term effects on the child's development, reducing the likelihood that the child will have a suboptimal developmental trajectory. Higher maternal education is associated with better nutritional status and a better quality environment for growing up, which contributes to more favorable cognitive development. In children who were born with low birth weight or intrauterine growth retardation, a long-term delay in cognitive performance was observed. Some analyses indicate that the difference between these groups and the group with normal birth weight increases with age, which potentially implies the need for early nutritional intervention in order to alleviate long-term consequences (1). On the other hand, limited periods of follow-up in some studies make it difficult to assess the sustainability of effects of intervention programs in the long term, so the implementation of interventions that last at least three months and encompass a larger sample of subjects has been suggested for more precise conclusions.

Some research groups have examined the effects of specific food products rich in micronutrients and macronutrients on children at risk of stunting. These results emphasize the complexity of this problem and suggest that supplementation must be part of broader package of measures that also includes socioeconomic components (2). In addition to direct effects of micronutrients such as iron, iodine or vitamin D on neurological development, there is interest in fatty acids that participate in the processes of neural communication and that can have a positive impact on the velocity of information processing in children (3). Interventions that combine a nutrition-

cijalno-emocionalne veštine, dok su rezultati vezani za izvršne funkcije kod dece predškolskog uzrasta manje konzistentni (4). To može ukazivati na to da puni efekat ovih kognitivnih strategija dolazi do izražaja tek kada deca razviju viši nivo metakognitivnih sposobnosti.

Dodatni aspekt predstavljaju fizičke aktivnosti integrisane u pedagoški okvir, koje kroz kombinaciju spontanih aktivnosti na otvorenom i strukturisane igre u okviru programa stvaraju uslove za paralelni razvoj motorike i kognitivnih veština. Autori ističu interaktivnu primenu nastavnih strategija koja doprinosi složenosti zadataka u igri, što može stimulisati inhibicioni kontrolni mehanizam kod dece. Na taj način fizička aktivnost postaje ne samo sredstvo unapređenja motoričkih veština, već i alat za modifikaciju obrazaca pažnje i samoregulacije. Važno je napomenuti da pristupi koji kombinuju strukturisane programe sa elementima slobodne igre mogu ostvariti bolje rezultate u poređenju sa onima koji se oslanjaju isključivo na jedan tip aktivnosti (5). Spontana igra na otvorenom pojačava efikasnost formalnih intervencija u razvoju finih motoričkih veština, dok metodološke neusaglašenosti u proceni efektivnosti nutritivnih protokola, poput MIND i mediteranske dijete, ukazuju na nedovoljno konzistentne dokaze u vezi sa njihovom ulogom u prevenciji kognitivnih razvojnih poremećaja (6). Razmatranje svih ovih rezultata ukazuje na to da istraživanje nutritivnih intervencija kod dece uzrasta od 2 do 6 godina mora obuhvatiti različite dimenzije, od prenatalnog statusa majke do oblika igre u okviru edukativnih programa, kako bi se u potpunosti razumeo njihov uticaj na razvoj kognitivnih sposobnosti.

Ovaj pregledni rad ima za cilj da ispita uticaj nutritivnih intervencija na razvoj kognitivnih sposobnosti dece uzrasta od dve do šest godina.

Metode

U okviru ovog preglednog rada uključeni su svi radovi napisani na engleskom jeziku do kojih se došlo na osnovu pretraživanja nekoliko elektronskih baza podataka: PubMed, NCBI, SCIndex, Google Scholar. U cilju pretraživanja literature korišćene su sledeće ključne reči: kognicija, predškolski uzrast i ishrana. Pretraživanje literature je sprovedeno za period od 2015. do 2025. godine.

Teorijski okvir kognitivnog razvoja dece predškolskog uzrasta

Razvoj kognitivnih sposobnosti kod dece uzrasta od 2 do 6 godina odvija se u okviru kompleksne interakcije bioloških predispozicija, okruženja i iskustava koja dete stiče u prvim godinama života. Kognitivni razvoj u ovom periodu obuhvata progresivno usvajanje osnovnih mentalnih funkcija poput pažnje, pamćenja, percepcije, sposobnosti rešavanja problema, jezičkih veština i metakognitivnih strategija. Struktura teorijskog okvira mora uzeti u obzir temeljne neuropsihološke procese koji sazrevaju u ovom periodu, kao i njihovu povezanost sa socijalnim, emocionalnim i motoričkim dimenzijama razvoja. Neuromaturacija tokom ranog detinjstva se odvija brzim tempom, što ovaj period čini posebno osetljivim na spoljašnje stimuluse. Povezanost između motorike i kognicije postaje očigledna kada se sagledaju istraživanja koja ukazuju na to da koordinacione sposobnosti, bilateralna kontrola tela i fina motorika imaju izraženiju korelaciju sa parametrima kao što su vizuelna obrada informacija, radno pamćenje i izvršne funkcije u poređenju sa grubim motoričkim veštinama (7). Mehanizmi ovog odnosa su višeslojni: povećano snabdevanje mozga kiseonikom tokom fizičke aktivnosti može uticati na sinaptičku plastičnost i nivoe neurotransmitera, dok složene motoričke aktivnosti zahtevaju istovremeno angažovanje pažnje, perceptivnih procesa i planiranja.

Kognitivni razvoj dece sa različitim izazovima u neuropsihološkom funkcionisanju zahteva specifican teorijski pristup. Na primer, kod dece sa intelektualnim teškoćama proces edukacije obuhvata dijagnostički segment koji procenjuje individualne karakteristike deteta, kao i specifično osmišljene programe podrške čiji cilj je stimulacija kompenzatornih procesa (8). Ovakvi programi oslanjaju se na defektološka, logopedska i medicinska znanja kako bi se stvorili optimalni uslovi za napredak u različitim domenima kognitivnog razvoja. Na neurobiološkom nivou, ishrana ima važnu ulogu u uspostavljanju optimalnih uslova za razvoj kognitivnih funkcija. Nedostatak esencijalnih makro- i mikronutrijenata u periodu ubrzanog rasta može dovesti do trajnog oštećenja funkcionalnih sistema mozga. Kod dece sa nutritivnim poremećajima zabeleženi su slabiji rezultati na testovima koji mere jezičke sposobnosti, prostornu orijentaciju ili fleksibilnost mišljenja (9). Osim direktnog uticaja hranljivih materija na neuronske procese, efekti se ogledaju i kroz smanjenu energiju potrebnu za angažovanje u istraživačkim aktivnostima, čime se indirektno utiče na nivo kognitivne stimulacije. Socioekonomski status porodice takođe

al component with educational approaches, such as Head Start REDI and Preschool PATHS programs, have effects on social-emotional skills, but results related to executive functions in preschool children are less consistent (4). This may mean that the full potential of these cognitive strategies comes to the fore only when children develop a higher level of metacognitive abilities.

One additional aspect includes physical activities integrated into the pedagogical framework, which through the combination of spontaneous activities outside and structured play within the program create conditions for the parallel development of motor and cognitive skills. The authors emphasize the interactive use of teaching strategies which contributes to the complexity of tasks in the game, which can stimulate the inhibitory control mechanism in children. In this way, physical activity becomes not only a means of improving motor skills, but also a tool for modifying patterns of attention and self-regulation. It is important to note that approaches that combine structured programs with elements of free play can achieve better results than those that rely exclusively on one type of activity (5). Spontaneous outdoor play enhances the effectiveness of formal interventions in the development of fine motor skills, while methodological inconsistencies regarding the effectiveness of nutritional protocols, such as MIND and Mediterranean diet, indicate contradictory results in the prevention of developmental cognitive deficits (6). The analysis of all these results indicates that the research of nutritional interventions in children aged 2 to 6 years must include different dimensions, from the prenatal status of the mother to the form of play together with educational programs, in order to fully understand their impact on the development of cognitive abilities.

The aim of this review article was to examine the impact of nutritional interventions on the development of cognitive abilities in children aged 2 to 6 years.

Methods

This review article included only papers written in English based on the literature search that was conducted using the following databases: PubMed, NCBI, SCIndex, Google Scholar. The following key words were used for the literature search: cognition, preschool age, nutrition. The literature search was conducted for the period 2015 to 2025.

The theoretical framework of cognitive development in preschool children

The development of cognitive abilities in children aged 2 to 6 takes place within the complex interplay of biological predispositions, environment and experiences that a child acquires in the early years of life. Cognitive development in this period includes the progressive acquisition of basic mental functions such as attention, memory, perception, problem-solving abilities, language skills, and metacognitive strategies. The structure of the theoretical framework must take into account basic neuropsychological processes that mature in this period, as well as the way in which they are related to social, emotional and motor dimensions of development. Neuromaturation during early childhood occurs at a rapid pace, which makes this period particularly vulnerable to external stimuli. The connection between motor skills and cognition becomes evident in studies which point to the fact that coordination abilities, bilateral body control and fine motor skills have a more pronounced correlation with parameters such as visual information processing, working memory and executive functions in relation to gross motor skills alone (7). The mechanisms of this relationship are multifaceted: increased oxygen supply to the brain through physical activity can affect the synaptic plasticity and neurotransmitter concentrations, while complex motor activities demand the simultaneous engagement of attention, perceptual processes and planning.

Cognitive development of children with different challenges in neuropsychological functioning requires a special theoretical approach. For example, in children with intellectual disabilities, the educational process combines a diagnostic segment – which evaluates the child's individual characteristics – with specifically designed support programs aimed at stimulating compensatory processes (8). Such programs rely on special education, speech therapy and medical knowledge in order to create optimal conditions for advancements in the domain of cognition. In the domain of neurobiology, nutrition plays an important role in the maturation of cognitive functions. The lack of essential macro and micronutrients during the period of rapid growth can lead to permanent damage to the brain's functional systems. In children with nutritional disorders, lower results were recorded on tests that measure language abilities, spatial orientation or flexibility of thinking (9). Apart from the direct impact of nutri-

zauzima centralno mesto unutar teorijskog okvira kognitivnog razvoja. Viši stepen obrazovanja majke povezana je sa boljom ishranom deteta i širim spektrom kognitivno stimulativnog materijala kućnog okruženja (10). U tim slučajevima deca češće imaju pristup knjigama, slikovnicama i interaktivnim edukativnim igračkama koje doprinose razvoju pažnje, pamćenja i logičkog zaključivanja. Analiza posebnih razvojnih profila pokazuje da kod određenih neuroloških sindroma postoji paralelna regresija motoričkih i kognitivnih parametara (11,12). Vizuelne funkcije – koje prethode višim oblicima kognitivnog procesuiranja – mogu biti narušene pre pojave vidljivog opadanja opštih kognitivnih performansi. Ovi nalazi sugerišu teorijski model razvoja koji uključuje rane prekognitivne indikatore kao prognostičke faktore budućih poteškoća.

Nutritivne intervencije u ranom detinjstvu

Nutritivne intervencije u ranom detinjstvu predstavljaju specifičan set aktivnosti osmišljen da u periodu brzog rasta i intenzivnog neurološkog razvoja obezbedi adekvatne uslove za optimalan razvoj kognitivnih funkcija. Period prvih nekoliko godina života, posebno prve dve godine, često se opisuje kao period povećane osetljivosti na nutritivne i stimulativne faktore, ali dostupni podaci ukazuju na to da značajne mogućnosti za unapređenje razvoja postoje i nakon tog intervala (13). Meta-analize više desetina interventnih studija pokazuju da su vrsta i količina nutrijenata ključni za efikasnost programa (13). Suplementacija koja obuhvata pet ili više hranljivih materija ima jači uticaj na razvoj kognitivnih sposobnosti u poređenju sa suplementacijom samo jednim ili nekoliko nutrijenata. U zemljama sa čestim višestrukim nutritivnim deficitima ovaj pristup može nadoknaditi nutritivne nedostatke koje pojedinačna suplementacija ne može. Posebno se ističu mikroelementi poput gvožđa, cinka, kalcijuma i vitamina B12, kao i proteini, zbog njihove uloge u sintezi neurotransmitera, metabolizmu masnih kiselina u mozgu i rastu neuronskih struktura. Uzrast deteta kada se kreće sa intervencijama takođe igra važnu ulogu. Programi implementirani između 6. i 18. meseca života imaju najveću korist u pogledu kognitivnih ishoda (14), što je u skladu sa intenzivnim razvojem moždane mase i sinaptičkih veza u tom periodu. Međutim, efekti postignuti kod dece starije od 18 meseci variraju i zavise od širine nutritivne ponude – kod nekih starijih grupa pozitivan učinak se javlja kada su uključeni programi fortifikacije hrane ili školski obroci sa višestrukim nutrijentima.

Ograničenja infrastrukturne prirode u siromašnijim regionima otežavaju sprovođenje reprezentativnih studija i dugoročnog praćenja efekata intervencija. Uprkos tome, postoje nalazi koji sugerišu dugoročne koristi od određenih prehrambenih navika iz detinjstva. Na primer, svakodnevna konzumacija malih količina mesa posle perioda dojenja može biti povezana sa boljim kognitivnim funkcionisanjem u kasnijem životnom dobu (15), pri čemu proteini i mikronutrijenti iz mesa doprinose razvoju hipokampusa i hipotalamusa – struktura koje nastavljaju da sazrevaju tokom detinjstva i adolescencije. U mnogim zemljama sa niskim i srednjim prihodima, biološki rizici povezani sa siromaštvom doprinose dugotrajnom uticaju nutritivnog statusa na razvoj. Posmatranja pokazuju da linearni rast tokom prvih 1 000 dana života korelira sa boljim motoričkim i kognitivnim sposobnostima (16), a napredak telesne visine nakon tog perioda može biti značajan indikator budućih kognitivnih ishoda. Nutritivne intervencije usmerene na ove parametre mogu doprineti ne samo smanjenju učestalosti zastoja u rastu već i poboljšanju socijalnih funkcija, budući da neurokognitivne sposobnosti posreduju u odnosu između ishrane i socijalnog ponašanja (17).

Znanje roditelja i/ili staratelja o važnim mikronutrijentima ponekad se bolje razvija kroz kontinuirano učešće u zdravstvenim programima ili kroz sopstveno iskustvo hranjenja dece (18). Ovo ukazuje na potencijalno jedinstvenu strategiju: edukativnu komponentu usmeriti ka onima koji već poseduju određeni stepen informisanosti, kako bi se optimizovala primena nutritivnih smernica u praksi. Specifične populacije, kao što su deca sa cerebralnom paralizom, zahtevaju prilagođene nutritivne protokole. Kod njih su energetske potrebe niže nego kod vršnjaka tipičnog razvoja (19), ali su potrebe za kvalitetnom nutritivnom podrškom jednako važne zbog uticaja na sastav tela, zdravlje kostiju, sazrevanje mozga i opšte funkcionisanje.

Efekti nutritivnih intervencija na kognitivne ishode

Analizirajući rezultate različitih istraživanja, uočava se da efekti nutritivnih intervencija na kognitivne ishode kod dece uzrasta od 2 do 6 godina imaju izraženu varijabilnost, koja zavisi od vrste i trajanja intervencije, kao i početnog nutritivnog i zdravstvenog statusa učesnika. Multinutrijentne suplementacije često daju širi spektar poboljšanja u kognitivnih

ents on neural processes, the effects are also reflected in the reduced energy necessary for engaging in research activities, which directly affects the level of cognitive stimulation. The socioeconomic status of the family also takes a central place within the theoretical framework of cognitive development. Higher maternal education is associated with better child nutrition and a wider range of cognitively stimulating material in the home environment (10). In those cases, children more often have access to books, picture books or interactive educational toys that contribute to the development of attention, memory and logical reasoning. The analysis of special developmental profiles shows that in certain neurological syndromes there is a parallel regression of motor and cognitive parameters (11,12). Visual functions – which precede higher forms of cognitive processing – can be impaired before the appearance of a visible decline in general cognitive performance. These findings suggest the theoretical model of development that includes early precognitive indicators as prognostic factors of future difficulties.

Nutritional interventions in early childhood

Nutritional interventions in early childhood represent a specific set of activities designed to provide adequate resources for the optimal formation of cognitive functions during the period of rapid growth and high neurological development. The period of the first few years of life, especially the first two years, is often described as a window of sensitivity to nutritional and stimulating factors, but available data indicate that a significant opportunity for improving development exists even after that interval (13). Meta-analyses of dozens of intervention studies show that that the type and amount of nutrients are essential for the effectiveness of the program (13). Supplementation that includes five or more nutrients has a stronger impact on cognitive development than supplementation with only one or a few nutrients. In countries with frequent multiple deficiencies, this approach can close nutritional gaps that individual supplementation cannot. Microelements such as iron, zinc, calcium and vitamin B12, as well as proteins, are especially important due to their roles in the synthesis of neurotransmitters, the metabolism of fatty acids in the brain and the growth of neuronal structures. The period of the child's life when interventions begin plays an important role. Programs implemented between 6 and 18 months of age have the largest benefit in terms of cognitive outcomes (14), which is compatible with the biology of intensive development of brain mass and synaptic connections during this period. However, effects achieved in children older than 18 months vary and depend on the breadth of nutritional provision – in some older groups a positive effect occurs when food fortification programs or school meals with multiple nutrients are included.

The limitations related to infrastructure in poorer regions make it difficult to conduct representative studies and long-term follow-up of the effects of interventions. In spite of this, there are findings that suggest long-term benefits of certain childhood eating habits. For example, consumption of small amounts of meat daily after the period of breastfeeding may be associated with better cognitive functioning later in life (15), with proteins and micronutrients from meat contributing to the development of the hippocampus and hypothalamus – structures that mature long during childhood and adolescence. In many low- and middle-income countries, biological risks associated with poverty contribute to the lasting impact of nutritional status on development. Studies show that linear growth during the first 1000 days of life correlates with better motor and cognitive abilities (16), while height after that period can be a significant indicator of future cognitive outcomes. Nutritional interventions targeting these parameters can contribute not only to reducing the incidence of short stature but also to improving social functions because neurocognitive ability acts as the mediator between nutrition and social behavior (17).

Parents' or caregivers' knowledge about important micronutrients sometimes develops better through continuous participation in health programs or their own feeding experience (18). This indicates a potentially unique strategy: to direct the educational component towards those who already possess a certain degree of informedness in order to optimize the implementation of nutritional guidelines in practice. Specific populations such as children with cerebral palsy require customized nutritional protocols. Their energy needs are lower compared to their peers that have typical development (19), however, needs for quality nutritional support are equally important due to the influence on body composition, bone health, brain maturation and general functioning.

The effects of nutritional interventions on cognitive outcomes

The analysis of results of various studies shows that the effects of nutritional interventions on cog-

funkcija u odnosu na ciljane suplementacije pojedinačnim vitaminima ili mineralima. Na primer, kod grupa koje su dobijale kombinovane multivitaminske preparate zabeleženo je napredovanje verbalne i vizuelne memorije, povećanje brzine vizuomotornog procesuiranja, kao i poboljšanje strategijskog generisanja rešenja u zadacima i unapređenje radnog pamćenja (16,17). Takav učinak se ne javlja u istom obimu kod izolovanih nutritivnih intervencija, gde poboljšanja uglavnom obuhvataju specifične funkcije, poput verbalne memorije ili određenih tipova pažnje. Uočena korist od mikronutrijenata, poput vitamina D, povezana je sa kognitivnim domenima kao što su opšti koeficijent inteligencije (IQ) i procesi inhibicije odgovora, premda rezultati nisu uvek konzistentni zbog razlika u doziranju i metodama procene kognitivnih funkcija. Postoje studije koje pokazuju da male promene u ishrani, poput povećanog unosa vitamina C kod populacija sa niskim unosom voća i povrća, mogu dovesti do poboljšanja kognitivnih performansi kroz mehanizme povezane sa ćelijskim metabolizmom askorbinske kiseline i sintezom neurotransmitera (20). Po svoj prilici, ovakvi efekti su izraženiji kod dece koja polaze od stanja deficita nego kod one sa već adekvatnim nutritivnim statusom. Kod određenih zdravstvenih stanja, dodatni unos mikronutrijenata može imati specifičan učinak na razvoj.

Vitamin B12 pokazuje pozitivan uticaj na motorički razvoj kod odojčadi sa deficitima (21), a teorijski bi mogao imati sličan doprinos kognitivnim funkcijama putem učešća u sintezi mijelina i metaboličkom radu neurona. Ipak, istraživanja koja direktno povezuju suplementaciju B12 sa izvršnim funkcijama ili pamćenjem kod predškolske dece još su ograničena, pa zaključci ostaju okvirni. Efekti nutritivnih intervencija na decu sa cerebralnom paralizom zahtevaju posebno sagledavanje. Smanjena fizička aktivnost ovih grupa podrazumeva drugačiju dinamiku nutritivne podrške, pri čemu adekvatan unos hrane bogate mikronutrijentima može ublažiti fiziološke prepreke za razvoj mozga (19). Time se potencijalno posredno utiče na komunikacione sposobnosti, pažnju ili radno pamćenje. Kod malnutricije je dokazano da deca imaju slabije rezultate na testovima radnog pamćenja, vizuelne konstrukcije, učenju i memoriji (22). Efekti intervencije su vidljivi kroz pomeranje distribucije kognitivnih skorova ka višim vrednostima u interventnoj grupi tokom vremena. Pri tome treba naglasiti da određeni aspekti, poput motoričke koordinacije, mogu ostati manje podložni uticaju nutritivnog statusa nego ostali kognitivni domeni. Povezanost između prehrambenog unosa proteina i linearnog rasta sa kasnijim kognitivnim ishodima podržana je nalazima koji idu u prilog hipotezi da rast tokom prvih godina života vodi ka boljoj spremnosti za kompleksne mentalne zadatke (23).

Nedovoljna dostupnost hrane ne samo da smanjuje kvalitet ishrane, već podstiče socijalno-emocionalna ponašanja koja negativno utiču na interakcije i mogućnost angažovanja u stimulativnim aktivnostima. Suplementacija mikronutrijentima na kratkoročnom nivou pokazuje da čak osmonedeljni program može promeniti nivoe vitamina B6, B12, folata i homocisteina u plazmi, uz uočena poboljšanja određenih aspekata pažnje ili memorije (20). Razlike između studija sličnog dizajna upućuju na to da isti suplement može izazvati promene različitih kognitivnih funkcija, zavisno od populacije i trajanja tretmana. Intervencije koje kombinuju fizičku aktivnost sa nutritivnim komponentama mogu doprineti razvoju izvršnih funkcija, uključujući inhibicionu kontrolu reakcija kod dece (5). Kada se spoljašnja stimulacija motorike udruži sa povećanim unosom esencijalnih nutrijenata, efekat se može proširiti na pažnju i organizaciju mišljenja.

Jedan od interesantnih aspekata odnosi se na korelaciju između biomarkera, poput nivoa BDNF-a (eng. *brain-derived neurotrophic factor*), i kognitivnih skorova (24). Mada direktna suplementacija nije primarni faktor koji menja nivo BDNF kod zdrave pedijatrijske populacije, prema dostupnim podacima, moguće je da poboljšana ishrana stimuliše neurogenezu i neuroplastičnost preko mehanizama snaženja mitohondrijalne efikasnosti ili zaštite DNK struktura (20).

Efikasnost programa takođe zavisi od konteksta implementacije. Kod populacija iz ruralnih područja ili siromašnijih sredina efekti mogu biti izraženiji, jer osnovna ishrana često ne pokriva ni minimalne potrebe za mikronutrijentima. Kod ovakvih grupa suplementacija višestrukim nutrijentima rezultira izraženijim poboljšanjem parametara pažnje, verbalnog izražavanja ili sposobnosti rešavanja problema u poređenju sa decom iz urbanih sredina, koja već imaju relativno stabilan nutritivni status. Ovi nalazi pokazuju složenu sliku u kojoj nutritivne intervencije – bilo kroz izolovane mikronutrijente poput vitamina D ili C, bilo kroz multivitaminske preparate – mogu imati merljivo pozitivan efekat na različite domene kognitivnog razvoja. Međutim, amplitude tih efekata zavise od početnog nutritivnog statu-

nitive outcomes in children aged 2 to 6 years have a pronounced variability that depends on the type and duration of the intervention, as well as on the initial nutritional and health status of participants. Multinutrient supplementation often produces a wider range of improvements in cognition than targeted supplementation with single vitamins or minerals. For example, in groups that received combined multivitamin preparations, improvements in verbal and visual memory were observed, as well as an increase in the speed of visual and motor processing, the improvement in the strategic generation of solutions in tasks and improvement of working memory (16,17). Such an effect does not occur to the same extent with isolated nutritional interventions, where improvements mainly involve specific functions such as verbal memory or certain type of attention. The observed benefit of micronutrients such as vitamin D has been associated with cognitive domains such as general intelligence quotient (IQ) and processes of response inhibition, although results are not always consistent due to differences in dosage and methods of cognitive assessment. There are studies which show that small dietary changes, such as increased vitamin C intake in populations with low fruit and vegetable intake can lead to improved cognitive performance through mechanisms related to cellular mechanisms of ascorbate and synthesis of neurotransmitters (20). These effects are presumably more pronounced in children starting from a state of deficit than in those with an already adequate nutritional status. In certain health conditions, additional intake of micronutrients can have a specific effect on development.

Vitamin B12 shows a positive effect on motor development in infants with deficits (21), and theoretically it could have a similar contribution to cognitive functions by participating in the synthesis of myelin and the metabolic work of neurons. However, studies that directly connect B12 supplementation with executive functions or memory in preschool children still have limitations, and therefore, conclusions remain tentative. The effects of nutritional interventions on children with cerebral palsy require special consideration. The reduced physical activity of these groups implies a different dynamic of nutritional support, while the adequate intake of food rich in micronutrients can alleviate physiological obstacles to brain development (19). This potentially influences communication skills, attention or working memory in an indirect way. It has been shown that malnourished children perform poor on tests of working memory, visual construction, learning and memory (22). The effects of the intervention are visible in the shift of distribution of cognitive scores towards higher values in the intervention group over time. It should be emphasized that certain aspects such as motor coordination can remain less affected by nutritional status than other elements of cognition. The interconnectedness between the dietary intake of proteins, linear growth and later cognitive outcomes is shown in findings that support the hypothesis that growth during the first years of life leads to better readiness for complex mental tasks (23).

The insufficient availability of food not only reduces the quality of nutrition, but also promotes social-emotional behaviors that negatively affect interactions and the ability to engage in stimulating activities. Short-term micronutrient supplementation shows that even an eight-week program can change plasma levels of vitamins B6, B12, folate and homocysteine with observed improvements in certain aspects of attention or memory (20). Differences between studies of similar design suggest that the same supplement may induce changes in different elements of cognition depending on the population and duration of treatment. Interventions that combine physical activity with nutritional components open an additional pathway for the development of inhibitory response control in children (5). When external motor stimulation is combined with increased intake of essential nutrients, the effect can spread to attention and thought organization.

One of the interesting aspects is the correlation between biomarkers such as the level of brain-derived neurotrophic factor (BDNF) and cognitive scores (24). Although direct supplementation is not the primary factor that alters BDNF in healthy pediatric population according to available data, improved nutrition may possibly contribute to healthy neurogenesis through mechanisms of enhancing mitochondrial efficiency or protecting DNA structures (20).

The effectiveness of the program also depends on the context of implementation. In populations from rural areas or poorer environments, the effects may be more pronounced because the basic diet does not often cover even the minimum needs for micronutrients. In these groups, the addition of multiple nutrients results in stronger improvements in parameters of attention, verbal expression or problem-solving ability than in children from urban

sa, zdravstvenog profila deteta, trajanja tretmana i načina integrisanja nutritivnih aktivnosti sa drugim stimulativnim faktorima, poput fizičke aktivnosti ili obrazovnih sadržaja. To sugeriše potrebu za personalizovanijim pristupom koji će uzeti u obzir ove varijable pri dizajniranju budućih interventnih programa.

Širi kontekst i implikacije

Posmatranje nutritivnih intervencija u ranom detinjstvu ne može se odvojiti od širih društvenih, zdravstvenih i obrazovnih okolnosti koje oblikuju njihovu efikasnost. Efekti koji su opisani u prethodnom delu rada ukazuju da nutritivne strategije nisu izolovan mehanizam, već deo složene mreže delovanja u kojoj socioekonomski status porodice, lokalni zdravstveni sistem i kulturni obrasci ishrane igraju značajnu ulogu. Na primer, evidentirano je da majke sa višim nivoom obrazovanja i boljim materijalnim uslovima češće primenjuju raznovrsnu ishranu bogatu mikronutrijentima, što se reflektuje na bolje rezultate dece u testovima pažnje i memorije (25). Time se potvrđuje da kvalitet ishrane zavisi ne samo od individualnih odluka, već i od dostupnosti resursa unutar zajednice.

Programi ranog obrazovanja koji integrišu nutritivnu komponentu sa pedagoškim modulima imaju potencijal da dugoročno utiču na socijalnu mobilnost dece iz siromašnijih sredina. Korišćenje školskog okruženja za distribuciju obroka bogatih mikronutrijentima, uz paralelno sprovođenje edukativnih aktivnosti prilagođenih predškolskom uzrastu, predstavlja mogućnost koja povezuje zdravstveni sektor sa obrazovnim institucijama (13). Takvi modeli podstiču kognitivni razvoj kroz simultano delovanje na fizičke i mentalne kapacitete deteta. Dodatno, višestruka korist proizilazi iz smanjenja prevalencije hronične malnutricije, koja negativno utiče na opšte zdravlje i sposobnost za učenje (26). Globalne zdravstvene inicijative, kao što su ciljevi održivog razvoja (eng. *Sustainable Development Goals* – SDG), uključuju smanjenje gladi i malnutricije kao ključne prioritete. Nutritivne intervencije osmišljene da poboljšaju status mikronutrijenata kod dece direktno doprinose ovim ciljevima (25), ali njihova implementacija zahteva prilagođavanje regionalnim uslovima. U regionima gde postoji dvostruki teret malnutricije – istovremeno prisustvo pothranjenosti i prekomerne težine – intervencije moraju balansirati između prevencije deficita i sprečavanja problema prekomerne telesne mase.

Zdravstveni sistemi imaju posebnu odgovornost u identifikovanju rizičnih grupa. Nacionalni programi skrininga novorođenčadi, poput onih koji otkrivaju metaboličke ili genetske poremećaje, mogu poslužiti kao osnova za usmeravanje dodatne nutritivne podrške ka deci koja su potencijalno ugrožena (27). Takođe, integracija nutritivnih protokola u programe prevencije hroničnog zaostojanja u rastu (eng. *stunting)* ima dugoročne implikacije na smanjenje učestalosti neurokognitivnog deficita kod populacija koje su pogođene hroničnom malnutricijom (26). Kulturne prakse ishrane određuju način na koji zajednica prihvata prehrambene intervencije. Na primer, sklonost ka jednostavnim ugljenim hidratima može ograničiti efekat programa koji promovišu kompleksne ugljene hidrate bogate vlaknima, uprkos njihovom dokazanom pozitivnom uticaju na kontrolu glukoze i metaboličku ravnotežu (28).

Efikasna komunikacija između zdravstvenih radnika i roditelja o važnosti izbora namirnica može biti presudna za održavanje učinka nakon završetka intervencije. Ekonomske implikacije ovakvih programa takođe su značajne. Prevencija kognitivnih deficita putem optimalne ishrane smanjuje potrebu za kasnijim ulaganjima u remedijacione obrazovne programe ili lečenje komplikacija koje proizlaze iz nutritivnog zastoja (13). Dugoročno, to može doprineti povećanju produktivnosti odraslih koji su imali kvalitetne uslove razvoja tokom ranog detinjstva. U kontekstu javnog zdravlja, ovakvi programi predstavljaju preventivnu strategiju koja povezuje nutritivne faktore sa socijalnim intervencijama. Praćenje efekata kroz longitudinalna istraživanja omogućava procenu trajnosti koristi, kao i prilagođavanje strategija prema promenama demografskih struktura ili ekonomskih pokazatelja u lokalnoj zajednici (29). Model povratne sprege (engl. *feedback loop*) između roditelja, nastavnika i deteta, koji proizilazi iz kontinuiranog podržavanja zdravih prehrambenih navika, može dugoročno stvoriti samo-ojačavajući ciklus kognitivnog napretka. Poseban aspekt implicira odnos između globalnog naučnog znanja o ishrani i lokalnih specifičnosti implementacije. Intervencije koje dolaze iz međunarodnih zdravstvenih organizacija često zahtevaju adaptaciju kako bi bile kompatibilne sa tradicionalnim načinom ishrane, infrastrukturom distribucije hrane i nivoom edukacije stanovništva (17). Bez ovog prilagođavanja može doći do nedovoljnog angažovanja ciljnih grupa ili kratkoročnog efekta koji se brzo gubi po završetku projekta. Ove implikacije jasno pokazuju da nutritivni programi u

areas that already have a relatively stable nutritional fund. These findings show a complex picture where nutritional interventions – either through isolated micronutrients such as vitamin D or C or through multivitamin preparations – can have a measurable positive effect on different domains of cognitive development. However, the amplitudes of those effects depend on the initial nutritional status, the child's health profile, the duration of treatment and the way of integrating nutritional activities with other stimulating factors such as physical activity or educational contents. This suggests the need for a more personalized approach that would take all these variables into account when designing future intervention programs.

Wider context and implications

The analysis of nutritional interventions in early childhood cannot be separated from wider social, health and educational circumstances that shape their effectiveness. The effects described in the previous part of this study indicate that nutritional strategies are not an isolated mechanism but part of a complex network of actions, in which the socioeconomic status of the family, the local health system and cultural eating patterns play a significant role. For example, it has been observed that mothers with a higher level of education and better material conditions more often apply a varied diet rich in micronutrients, which is reflected in better results of children on tests of attention and memory (25). Thus, it has been confirmed that quality nutrition depends not only on individual decisions but also on the availability of resource within the community.

Programs of early education that integrate a nutritional component with pedagogical modules have the potential to influence the long-term social mobility of children from poorer environments. Using the school environment to distribute meals rich in micronutrients, with the parallel implementation of educational activities adapted to the preschool age, represents an opportunity that connects the health sector and educational institutions (13). Such models encourage cognitive development through simultaneous actions related to child's physical and mental capacities. In addition, multiple benefits arise from the reduction in the prevalence of chronic malnutrition that negatively affects general health and learning abilities (26). Global health initiatives such as Sustainable Development Goals (SDGs) include reducing hunger and malnutrition as key priorities. Nutritional interventions designed to improve the status of micronutrients in children contribute to these goals directly (25), but their implementation requires adaptation to regional conditions. In regions, where there is a double burden of malnutrition – the simultaneous presence of malnutrition and overweight – interventions must balance between preventing deficits and preventing overweight.

Health systems have a special responsibility in identifying groups at risk. National newborn screening programs, such as those that detect metabolic or genetic disorders, can serve as a basis for directing additional nutritional support to children who are potentially at risk (27). Also, the integration of nutritional protocols into programs for the prevention of chronic stunting has long-term implications for reducing the frequency of neurocognitive deficits in populations currently affected by chronic malnutrition (26). Cultural dietary practices determine how a community accepts nutritional interventions. For example, a preference for simple carbohydrates may limit the effect of programs that promote complex carbohydrates rich in fibers, despite their proven positive impact on glucose control and metabolic balance (28).

Effective communication between health professionals and parents about the importance of food choices can be crucial for maintaining effects after the intervention is over. The economic implications of such programs are also important. The prevention of cognitive deficits through optimal nutrition reduces the need for later investments in remedial educational programs or treatment of complications arising from nutritional failure (13). In the long term, it can contribute to the increased productivity of adults who had quality conditions of development during early childhood. In the context of public health, such programs represent a preventive strategy that connects nutritional factors with social interventions. Monitoring the effects through longitudinal studies enables the assessment of the durability of benefits, as well as the adjustment of strategies according to changes in demographic structures or economic indicators of the local community (29). The model of feedback loop between parents, teachers and children which comes from the continuous support of healthy eating habits can create a cycle of cognitive progress in the long term. A special aspect implies the relationship between the global scientific knowledge about nutrition and the local specificities of implementation. Interventions that come from in-

ranom detinjstvu funkcionišu najefikasnije kada su deo šire strategije uključivanja zajednice, koordinacije između sektora zdravlja i obrazovanja, te socioekonomske politike koja omogućava kontinuirani pristup kvalitetnoj hrani (22).

Preporuke za buduća istraživanja

Buduća istraživanja potrebna su da bi se razjasnile nejednakosti u rezultatima koji prate nutritivne intervencije kod dece različitog uzrasta. Trenutni nalazi ukazuju na varijacije koje proizlaze iz različitih kombinacija mikronutrijenata, trajanja programa i konteksta implementacije, ali je teško jasno izdvojiti pojedinačne mehanizme zbog heterogenosti studija (14). Potrebna su rigorozna poređenja multinutrijentnih i mononutrijentnih protokola kroz randomizovane kontrolisane studije koje će pratiti decu duže od jedne godine, kako bi se procenila održivost efekata. Takođe, dugoročna merenja trebalo bi da uključe procenu više domena kognitivnog razvoja – pažnje, radnog pamćenja, verbalnih sposobnosti, izvršnih funkcija – što će omogućiti kompleksniju interpretaciju rezultata u odnosu na dosadašnje jednostavnije testove. Uz to, budući projekti morali bi da standardizuju metode merenja nutritivnog unosa i statusa. Korišćenje laboratorijskih biomarkera (npr. serumskih koncentracija gvožđa, folata ili vitamina B12) u kombinaciji sa samoprocenom ishrane može smanjiti rizik od pristrasnosti usled pogrešno prijavljenog unosa (23). Posebno interesantno bilo bi povezati biomarkere sa neurofiziološkim pokazateljima, poput nivoa BDNF-a ili elektroencefalografskih parametara pažnje i memorije, čime bi se otvorilo pitanje mehanizama posredovanja između ishrane i neurorazvoja (20). Takva korelacija može pružiti snažne dokaze o direktnim neurobiološkim efektima suplementacije.

Potrebno je i proširenje populacijskih okvira istraživanja. Veći broj studija fokusira se na urbane sredine, dok ruralne oblasti ostaju slabije zastupljene, uprkos tome što često imaju veće stope malnutricije (27). U ovim područjima može biti posebno relevantno kombinovati nutritivne intervencije sa lokalnim programima obuke nastavnika i roditelja o važnosti raznovrsne ishrane. Ovde se javlja i pitanje kulturne adaptacije, te istraživanja treba da dokumentuju kako se prehrambene preporuke uklapaju u tradicionalne obrasce i dostupnost namirnica na lokalnom tržištu. Kada je reč o ciljnoj populaciji, istraživanja bi trebalo da uključe i decu sa posebnim zdravstvenim potrebama. Na primer, kod dece sa cerebralnom paralizom optimalan nutritivni protokol mora uzeti u obzir smanjenu potrošnju energije i specifične metaboličke potrebe (19). Longitudinalno praćenje efekata prilagođenih intervencija kod ovih grupa može pružiti podatke koji će definisati personalizovane programe ishrane i stimulacije kognitivnog razvoja. Bilo bi korisno nastaviti eksperimentisanje sa integrisanim pristupima koji kombinuju fizičku aktivnost sa nutritivnim komponentama. Modeli koji uključuju strukturisane motoričke igre zajedno sa multinutrijentnom podrškom mogli bi da budu testirani kroz višefaktorske dizajne kako bi se jasno definisalo sinergijsko dejstvo ovih komponenti (5).

Promene u rutini, rasporedu obroka i socijalnom okruženju mogu uticati na održavanje stečenih kognitivnih koristi. Praćenje učenika do kraja prvog ciklusa osnovnog obrazovanja moglo bi pokazati koliko je sprovedena intervencija doprinela trajnoj spremnosti za formalno učenje (13).

Nedovoljno istražen aspekt odnosi se na prekoncepcijski period majke. Budući projekti mogli bi uključiti praćenje žena od perioda pre trudnoće kako bi se procenio uticaj njihovog nutritivnog statusa na sastav mleka, a potom i na razvoj deteta (30). Ova linija istraživanja može pružiti argumente za šire populacione strategije koje počinju pre rođenja deteta.

Posmatrajući sve ove smernice zajedno, postaje jasno da buduća istraživanja moraju biti višeslojna: obuhvatiti različite populacije, standardizovati metode merenja, pratiti dugoročnost efekata, integrisati teorijske modele razvoja, testirati kombinovane pristupe i sagledati ekonomske implikacije intervencija. Pri tome ne treba zanemariti ni uticaj socioekonomskog statusa porodice, jer on oblikuje početni kognitivni potencijal deteta.

Zaključak

Razvoj kognitivnih sposobnosti dece uzrasta od 2 do 6 godina pokazuje složenu povezanost sa nutritivnim statusom, pri čemu nutritivne intervencije mogu ostvariti pozitivne efekte, posebno kada su usmerene na kritične periode rasta i kombinovane sa drugim stimulativnim faktorima. Višestruka suplementacija mikronutrijentima često pokazuje širi spektar koristi u oblastima kao što su memorija, pažnja i izvršne funkcije, u poređenju sa ciljanim, pojedinačnim nutritivnim intervencijama. Međutim, intenzitet i trajnost ovih efekata variraju pod uticajem početnog zdravstvenog stanja deteta, socioekonomskog konteksta porodice i kapaciteta lokalnog sistema da održi programe. Efikasnost je veća kada se

ternational health organizations often require adaptation in order to be compatible with the traditional way of eating, the infrastructure of food distribution and the level of education of the population (17). Without this adjustment, there may be insufficient engagement of target groups or a short-term effect that is quickly lost after the end of the project. These implications clearly show that early childhood nutrition programs work effectively when they are part of a broader strategy of community involvement, coordination between health and education sectors, and socioeconomic policies that enable the continued access to quality food (22).

Recommendations for future research

Further research is needed to clarify disparities in outcomes following nutritional interventions in children of different age. Current findings point to variations that arise from different micronutrient combinations, duration of programs and context of implementation, but it is difficult to clearly isolate individual mechanisms due to the heterogeneity of studies (14). Rigorous comparisons of multinutrient and mononutrient protocols through randomized controlled studies that would follow children for more than one year are needed to assess the sustainability of effects. Also, long-term measurements should include the assessment of several domains of cognitive development – attention, working memory, verbal abilities, executive functions – which will enable a more complex interpretation of results compared to simpler tests that have been conducted so far. In addition, future projects should standardize the methods of measuring nutritional intake and status. The use of laboratory biomarkers (e.g. serum concentrations of iron, folate or vitamin B12) in combination with self-reported dietary intake can reduce the risk of bias due to misreported intake (23). It would be particularly interesting to connect biomarkers with neurophysiological indicators such as the level of BDNF or electroencephalographic parameters of attention and memory, which would open the question of mechanisms of mediation between nutrition and neurodevelopment (20). Such a correlation may provide strong evidence about direct neurobiological effects of supplementation.

It is also necessary to expand the population framework of research. Most studies focus on urban areas, while rural areas remain less represented, although they often have higher rates of malnutrition (27). In these areas, it may be particularly relevant to combine nutritional interventions with local training programs of teachers and parents about the importance of varied diet. The question of cultural adaptation also arises here, so studies should document how dietary recommendations fit into traditional patterns and the availability on the local market. When it comes to the target population, studies should also include children with special health needs. For example, in children with cerebral palsy, an optimal nutritional protocol must take into account reduced energy expenditure and specific metabolic needs (19). Longitudinal follow-up of effects of customized interventions in these groups may provide data that would define personalized nutritional and cognitive development stimulation programs. It would be useful to continue experimenting with integrated approaches that combine physical activity with nutritional components. Models involving structured motor games together with multinutrient support could be tested through multifactorial designs to clearly define the synergistic effects of these components (5).

Changes in routine, meal schedule and social environment can affect the maintenance of acquired cognitive benefits. The follow-up of students until the end of the first cycle of primary education could show how much the implemented intervention contributed to permanent readiness for formal learning (13).

An insufficiently researched aspect relates to the mother's preconception period. Future projects could include monitoring mothers from the pre-pregnancy period to assess the impact of their nutritional status on milk composition and subsequent child development (30). This line of research can offer arguments for broader population strategies that begin before a child is born.

Considering all these guidelines together, it becomes clear that future research should be multifaceted: include different populations, standardize measurement methods, monitor long-term effects, integrate theoretical models of development, evaluate combined approaches and look at the economic implications of interventions. At the same time, the issue of socioeconomic status of the family is not negligible, because it shapes the child's initial cognitive potential.

Conclusion

The development of cognitive abilities of children aged 2 to 6 years shows a complex dependence

nutritivna podrška integriše u šire okvire koji uključuju obrazovne aktivnosti, fizičku aktivnost i podršku roditeljima. Primena takvih holističkih pristupa može podstaći paralelni napredak u razvoju motoričkih, socijalno-emocionalnih i kognitivnih veština, čime se stvaraju čvrste osnove za kasnije formalno obrazovanje. Posebnu pažnju zahteva populacija sa specifičnim zdravstvenim potrebama, kao i deca iz sredina sa ograničenim resursima, kod kojih su efekti intervencija često najuočljiviji usled prisustva osnovnih nutritivnih deficita. Za unapređenje ove oblasti neophodno je sprovoditi istraživanja sa dužim periodom praćenjem, standardizovanim merenjima i dizajnom koji jasno povezuje specifične nutritivne elemente sa odgovarajućim kognitivnim ishodima. Takvi podaci omogućili bi kreiranje preciznijih programa koji uzimaju u obzir individualne karakteristike deteta i specifičnosti okruženja, vodeći ka održivom unapređenju kognitivnog potencijala budućih generacija.

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on nutritional status, where nutritional interventions can have positive effects, especially when they are directed at critical periods of growth and combined with other stimulating factors. Multiple micronutrient supplementation often shows a wider range of benefits in areas such as memory, attention, and executive functions compared to targeted, single nutritional contributions. However, the magnitude and duration of these effects vary under the influence of the initial health status of the child, the socioeconomic context of the family, and the capacity of the local system to sustain the programs. Effectiveness is greater when nutritional support is integrated into broader frameworks that include educational activities, physical activity and support for parents. The implementation of such holistic approaches can encourage the parallel development of motor, social-emotional and cognitive skills, thereby creating solid foundations for later formal education. Special attention is required for the population with specific health needs, as well as children from environments with limited resources, where the effects of interventions are often the most noticeable due to the existence of basic nutritional deficits. In order to make improvements in this field, it is necessary to conduct research with longer follow-up periods, standardized measurements and design that clearly combines specific nutritional elements with appropriate cognitive outcomes. Such data will enable the creation of more precise programs, which would take into consideration child's individual characteristics and the specificities of the environment, leading to a sustainable improvement of the cognitive capital of future generations.

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