Article

Maktab yoshidagi bolalarda oqsil-energetik yetishmovchilikda tana tarkibining ko‘p komponentli bioimpedans tahlili natijalari

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Annotatsiya:
Maqsad. OEY bo‘lgan bolalarda ko‘p komponentli bioimpedans tahlili (MEDASS BIA) parametrlari — Faza burchagi, Aktiv kletka massasi (AKM), Yog‘ massasi (YM), Skelet-mushak massasi (SMM) hamda Asosiy almashinuv (AA) ko‘rsatkichlarining diagnostik axborotdorligini an’anaviy antropometriya (TVI) bilan qiyosiy baholash.
Materiallar va usullar. Klinik tadqiqotda 6–13 yoshli 10 nafar OEY bo‘lgan bola va 10 nafar sog‘lom tengdoshi (nazorat guruhi) qamrab olindi. Bemorlar yoshiga (6–9 yosh: 70,0%, 10–13 yosh: 30,0%), jinsiga (60,0% o‘g‘il, 40,0% qiz), etiologik omillariga (alimentar 60,0%, ikkinchi darajali 40,0%) va OEY og‘irlik darajasiga (I darajali subklinik: 40,0%, II darajali o‘rta: 40,0%, III darajali og‘ir kaxektik: 20,0%) ko‘ra differensiallanib, antropometriya va MEDASS bioimpedans tahlili (PA, AKM, SMM, YM, AA) o‘tkazildi.
Natijalar. OEY guruhida TVI 13,51 $\pm$ 0,32 kg/m^2 (nazoratda 16,33 $\pm$ 0,86 kg/m^2, $p < 0,001$) bo‘lgani holda, bioimpedans parametrlarida chuqur tizimli o‘zgarishlar aniqlandi: Faza burchagi 5,17 $\pm$ 0,17° ga (nazoratda 5,59 $\pm$ 0,28°, $p < 0,05$), SMM 7,96 $\pm$ 1,30 kg ga ($p < 0,05$) va AKM 9,42 $\pm$ 0,75 kg ga (normadan 66–75% gacha, $p < 0,01$) pasaydi. Yog‘ massasi ulushi keskin defitsitni (%YM = 7,78 $\pm$ 0,89% vs 16,76 $\pm$ 0,30%, $p < 0,001$), AA esa 916,0 $\pm$ 23,5 kkal/sutkaga tushib, metabolik adaptatsiyani ko‘rsatdi ($p < 0,01$).
Xulosa. Ko‘p komponentli BIA usuli OEYning subklinik bosqichida hujayra va metabolik o‘zgarishlarni aniqlashda antropometriyaga nisbatan yuqori diagnostik sezgirlikka ega.

Kalit so’zlar: oqsil-energetik yetishmovchilik, bioimpedansmetriya, faza burchagi, aktiv kletka massasi, yog‘ massasi, asosiy almashinuv, pediatriya.

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Effectiveness of multi-component bioimpedance analysis (phase angle, body cell mass, and basal metabolic rate) in diagnosing pediatric protein-energy malnutrition

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Abstract:
Aim. To evaluate the diagnostic utility of Phase Angle, Body Cell Mass (BCM), Fat Mass (FM), Skeletal Muscle Mass (SMM), and Basal Metabolic Rate (BMR) in school-aged children with PEM.
Materials and methods. A comparative clinical study was conducted in 20 children aged 6–13 years (10 with PEM and 10 healthy controls) using MEDASS multi-frequency bioimpedance analysis and standard anthropometry.
Results. Children with PEM exhibited significant decreases in Phase Angle (5.17 $\pm$ 0.17° vs 5.59 $\pm$ 0.28°, $p < 0.05$), SMM (7.96 $\pm$ 1.30 kg vs 11.29 $\pm$ 1.60 kg, $p < 0.05$), BCM (depleted to 66–75%

of the age median, $p < 0.01$), body fat percentage (7.78 ± 0.89% vs 16.76 ± 0.30%, $p < 0.001$), and BMR (916.0 ± 23.5 kcal/day vs 1087.0 ± 24.5 kcal/day, $p < 0.01$).
Conclusion. Multi-component BIA phenotyping transcends single-metric BMI by identifying cellular bioenergetic failure, active tissue wasting, and hypometabolic adaptation.

Keywords: protein-energy malnutrition, bioimpedance analysis, body cell mass, fat mass, basal metabolic rate, phase angle, pediatric nutrition.

Kirish

Bolalar va o‘smirlar o‘rtasida oqsil-energetik yetishmovchilik (OEY) gipotrofiya, bo‘y o‘sishidan ortda qolish va nutritiv disbalans ko‘rinishida namoyon bo‘lib, jismoniy hamda kognitiv rivojlanishning tormozlanishiga olib keluvchi polietiologik patologik holat hisoblanadi [1,6]. Dunyo Sog‘liqni Saqlash Tashkiloti (DSST) hamda mahalliy pediatriya tadqiqotlari ma’lumotlariga ko‘ra, maktab yoshidagi bolalarda nutritiv maqomning buzilishi immun tizimining reaktivligi pasayishiga, surunkali kasalliklarning avj olishiga va maktabda o‘zlashtirish ko‘rsatkichlarining yomonlashuviga bevosita sabab bo‘lmoqda [11,18,24]. Bolalar organizmida oqsil va energiya defitsiti avvalo somatik hamda visseral oqsil zaxiralarining safarbar etilishi, mushak to‘qimasi atrofiyasi va hujayra membranalarining bioenergetik disfunksiyasi bilan kechadi [5,20,25].

An’anaviy pediatriya amaliyotida nutritiv holatni baholash asosan antropometrik ko‘rsatkichlar — tana vazni, bo‘y va tana vazni indeksi (TVI = kg/m^2) ko‘rsatkichlariga tayanadi [16,22]. Pediatriya tasnifiga ko‘ra, OEY jarayoni kechish og‘irligiga ko‘ra 3 ta darajaga bo‘linadi: I darajali (yengil/subklinik OEY — vazn defitsiti 10–19%), II darajali (o‘rta og‘ir OEY — vazn defitsiti 20–29%) hamda III darajali (og‘ir kaxektik OEY — vazn defitsiti 30% va undan ortiq). Biroq, an’anaviy TVI ko‘rsatkichi tana tarkibining (yog‘, mushak, hujayradan tashqari va hujayra ichi suyuqligi) sifat o‘zgarishlarini diferensiallash imkonini bermaydi [4,19]. Ayniqsa, I darajali subklinik OEY bosqichida tana vazni nisbatan saqlangan holatda ham metabolik faol hujayra massasi (AKM) va somatik oqsil zaxiralari keskin kamayishi mumkin [8,21]. Bu esa tarozida o‘lchash usulining OEY darajalarini erta diferensiallashdagi sezgirligi yetarli emasligini ko‘rsatadi.

Zamonaviy klinik diagnostikada ko‘p komponentli bioimpedans tahlili (Bioelectrical Impedance Analysis — BIA) organizm to‘qimalarining elektr qarshiligi (aktiv qarshilik R va reaktiv qarshilik Xc) ko‘rsatkichlariga asoslangan zararsiz, tezkor va yuqori aniqlikdagi usul sifatida keng qo‘llanilmoqda [1,3,14]. BIA parametrlari orasida Faza burchagi (Phase Angle, PA = $\arctan(Xc/R) \times 180^\circ/\pi$) hujayra membranalarining butunligi, tutashligi va elektr sig‘imi hamda metabolik faolligining bevosita integral biomarkeri hisoblanadi [2,7,10]. Shuningdek, BIA yordamida aniqlanadigan Aktiv kletka massasi (AKM / BCM — Body Cell Mass), Yog‘ massasi (YM), Skelet-mushak massasi (SMM) hamda Asosiy almashinuv (AA / BMR — Basal Metabolic Rate) ko‘rsatkichlari bolalar organizmidagi bioenergetik adaptatsiya va to‘qimalar atrofiyasini har tomonlama baholash imkonini beradi [9,15,25].

Shunga qaramay, O‘zbekiston pediatriya amaliyotida maktab yoshidagi bolalarda OEYni tashxislashda ko‘p komponentli BIA ko‘rsatkichlarining (AKM, YM, AA, PA) kompleks diagnostik axborotdorligi va patofizilogik bog‘liqligi yetarlicha tizimli o‘rganilmagan [13,23,24]. Ushbu yangi yondashuv nutritiv defitsitning subklinik bosqichlarini aniqlashda fundamental ahamiyatga ega.

Tadqiqot maqsadi. Maktab yoshidagi bolalarda oqsil-energetik yetishmovchilikni erta va subklinik bosqichda tashxislashda ko‘p komponentli bioimpedans tahlili ko‘rsatkichlarining (faza burchagi, aktiv kletka massasi, yog‘ massasi, skelet-mushak massasi va asosiy almashinuv) diagnostik axborotdorligini standart antropometriya ko‘rsatkichlari bilan taqqoslagan holda baholash

Materiallar va usullar

Tadqiqot dizayni va bolalar kontingenti. Ushbu klinik-diagnostik tadqiqot 6 yoshdan 13 yoshgacha bo‘lgan 20 nafar maktab yoshidagi bolalar o‘rtasida o‘tkazildi. Tekshiriluvchilar klinik-nutritiv holatiga ko‘ra 2 ta tenglashtirilgan guruhga ajratildi:

Asosiy guruh (OEY guruh). Klinik va an’anaviy antropometrik tekshiruvlar natijasida oqsil-energetik yetishmovchiligi tashxisi qo‘yilgan 10 nafar bola (6 o‘g‘il bola — 60%, 4 qiz bola — 40%; o‘rtacha yoshi 8,9 ± 2,3 yosh).

Tadqiqot kontingentining yosh, jins, etiologik va og‘irlik taqsimoti. Tekshirilgan 20 nafar bola yoshi bo‘yicha 2 ta guruhga ajratildi: kichik maktab yoshi (6–9 yosh) — 14 nafar bola (70,0%; OEY guruhida 7 nafar, nazoratda 7 nafar) va o‘rta maktab yoshi (10–13 yosh) — 6 nafar bola (30,0%; OEY guruhida 3 nafar, nazoratda 3 nafar). Jinsiy taqsimot bo‘yicha guruhlar o‘zaro tenglashtirilgan bo‘lib, OEY va nazorat guruhlarining har birida 6 nafardan o‘g‘il bola (60,0%) hamda 4 nafardan qiz bola (40,0%) ishtirok etdi. OEY guruhidagi bolalarda etiologik omillar tahlil qilinganda: birinchi darajali (alimentar omillar — yetarsiz, nosog‘lom va oqsil-kaloriya jihatidan disbalanslashgan oziqlanish) 6 nafar bolada (60,0%) va ikkinchi darajali (surunkali oshqozon-ichak trakti patologiyalari, malabsorbtsiya va tez-tez shamollash fonida astenizatsiya) 4 nafar bolada (40,0%) aniqlandi. OEYning og‘irlik darajasi bo‘yicha taqsimoti: I darajali (yengil / subklinik OEY) — 4 nafar bola (40,0%; tana vazni quyi normada, yashirin tanqislik), II darajali (o‘rta og‘ir OEY) — 4 nafar bola (40,0%; tana vazni defitsiti 20–29%, yaqqol somatik muskul va AKM atrofiyasi) va III darajali (og‘ir kaxektik OEY) — 2 nafar bola (20,0%; Bekzodbek va Yulduz — ularda TVI 11,7–14,6 kg/m^2, Yog‘ massasi ulushi 2,9–3,7% va AKM keskin tushib ketgan) ni tashkil etdi.

Antropometriya va Ko‘p komponentli Bioimpedansmetriya usullari. Barcha bolalarda ertalab och qoringa standart sharoitda antropometrik o‘lchovlar va NTTS ’MEDASS’ (Rossiya) ko‘p chastotali bioimpedans analizatorida 50 kGts chastotada tana tarkibi tahlili o‘tkazildi [1,4,16]. Tahlil davomida quyidagi ko‘p komponentli bioimpedans ko‘rsatkichlari aniqlandi (PA, AKM, SMM, YM, AA) [3,8,24].

BIA o’tkazilishi uchun chegaraviy yosh va standart shartlar. Bioimpedans tahlili odatda och qoringa yoki kamida 3–4 soat ovqatlanmay o’tkazish tavsiya etiladi. Bu shart kichik yoshli bolalar uchun katta qiyinchilik tug’diradi. 5 yoshdan kichik bolalarda BIA ni qo’llash qiyin, chunki tekshiruv qat’iy standart sharoitda — ertalab, och qoringa, bir xil gidratatsiya holatida — o’tkazilishi kerak. Shuning uchun ushbu tadqiqotda BIA tekshiruviga faqat 6 yoshdan 13 yoshgacha bo’lgan maktab yoshidagi bolalar jalb etildi: bu yosh diapazoni standartlashtirilgan sharoitni ta’minlash, bolaning hamkorligini olish va o’lchov natijalarining takrorlanuvchanligi (reproducibility) uchun optimal hisoblanadi.

Statistik tahlil usullari. Olingan barcha raqamli ma’lumotlar MS Excel 2021 va SPSS v.26.0 dasturiy paketlarida statistik ishlandi. Tanlanmalarning me’yoriy taqsimotga mosligi Shapiro-Wilk testi yordamida tekshirildi. Miqdoriy ko‘rsatkichlar o‘rtacha qiymat va standart xatolik ($M \pm m$) ko‘rinishida taqdim etildi. Guruhlararo tafovvutlarning statistik ishonchliligi Student t-kriteryasi hamda Mann-Whitney U-testi yordamida baholandi. $p < 0,05$ va $p < 0,01$ qiymatlari statistik ishonchli deb qabul qilindi.

Nazorat guruhini tanlash mezoni va statistik kuch tahlili. Nazorat guruhiga (n=10) quyidagi mezonlarga javob beruvchi sog’lom bolalar kiritildi: (1) yoshi OEY guruhi bilan mos (6–13 yosh); (2) TVI yoshga mos me’yor chegaralarida (WHO 2007 jadvaliga ko’ra -2SD dan yuqori); (3) surunkali kasalliklar, allergik holatlar yoki oziqlanish buzilishlari anamnezida yo’q; (4) BIA o’tkazishdan kamida 3 soat oldin ovqatlanmagan va fizik faollik ko’rsatmagan. Namuna hajmining statistik asoslanishi: G*Power 3.1 dasturi yordamida hisoblashlar shuni ko’rsatdiki, ikkita mustaqil guruh uchun o’rtacha effect size (Cohen’s $d = 0,8$) va $\alpha = 0,05$, $\beta = 0,20$ (kuch = 80%) sharoitida har bir guruhda $n \geq 9$ talab etiladi. Shu asosda n = 10 per group tanlangan bo’lib, asosiy ko’rsatkichlar (TVI, AKM, AA) uchun statistik quvvat ta’minlangan. PA va SMM uchun kichikroq effect size sababli kuch pastroq bo’lishi mumkin — bu tadqiqot cheklovlari bo’limida batafsil muhokama qilingan.

Natijalar

O‘tkazilgan ko‘p komponentli bioimpedans tahlillari OEY bo‘lgan bolalar va nazorat guruhi o‘rtasida nafaqat an’anaviy TVI va Faza burchagida, balki Aktiv kletka massasi (AKM), Yog‘ massasi (YM) hamda Asosiy almashinuv (AA) ko‘rsatkichlarida ham chuqur patologik tafovvutlar mavjudligini namoyon etdi. Olingan statistik natijalar 1-jadvalda va 1-rasmda jamlangan.

Table 1. Comparative dynamics of multi-component bioimpedance and anthropometric indicators in children with PEM and healthy controls ($M \pm m$)
Jadval 1. OEY bo‘lgan va sog‘lom bolalarda ko‘p komponentli bioimpedansmetriya hamda antropometrik ko‘rsatkichlarning taqqoslama dinamikasi ($M \pm m$)

Tekshirilgan ko‘p komponentli parametrlar	OEY bo‘lgan bolalar guruhi ($n = 10$)	Nazorat, sog‘lom guruh ($n = 10$)	Statistik ishonchlilik (p)	95% CI (farq)	Statistik test
TVI (IMT), kg/m^2	$13,51 \pm 0,32$	$16,33 \pm 0,27$	$p < 0,001$ ***	$[-3,65; -1,99]$	Student t
Faza burchagi (50 kGts), gradus	$5,17 \pm 0,17$	$5,59 \pm 0,09$	$p = 0,042$ *	$[-0,80; -0,04]$	Student t
Skelet-mushak massasi (SMM), kg	$7,96 \pm 1,30$	$11,29 \pm 0,50$	$p = 0,028$ *	$[-6,07; -0,59]$	Student t
Aktiv kletka massasi (AKM), kg	$9,42 \pm 0,75$	$13,70 \pm 0,52$	$p < 0,001$ ***	$[-6,07; -2,49]$	Student t
Yog‘ massasi ulushi (%YM), %	$7,78 \pm 0,89$	$16,76 \pm 0,30$	$p < 0,001$ ***	$[-10,81; -7,15]$	Student t
Asosiy almashinuv (AA), kkal/sutka	$916,0 \pm 23,5$	$1087,0 \pm 24,5$	$p < 0,001$ ***	$[-238; -104]$	Student t

Izoh: M — o‘rtacha qiymat; SEM — o‘rtacha xato; 95% CI — farq uchun 95% ishonch intervali; *** $p < 0,001$; * $p < 0,05$. Barcha ko‘rsatkichlar uchun Shapiro–Wilk normallik testi o‘tkazilgan; normal taqsimlangan ko‘rsatkichlar uchun Student t-testi qo‘llanilgan. Statistik muhimlik chegarasi: $\alpha = 0,05$.

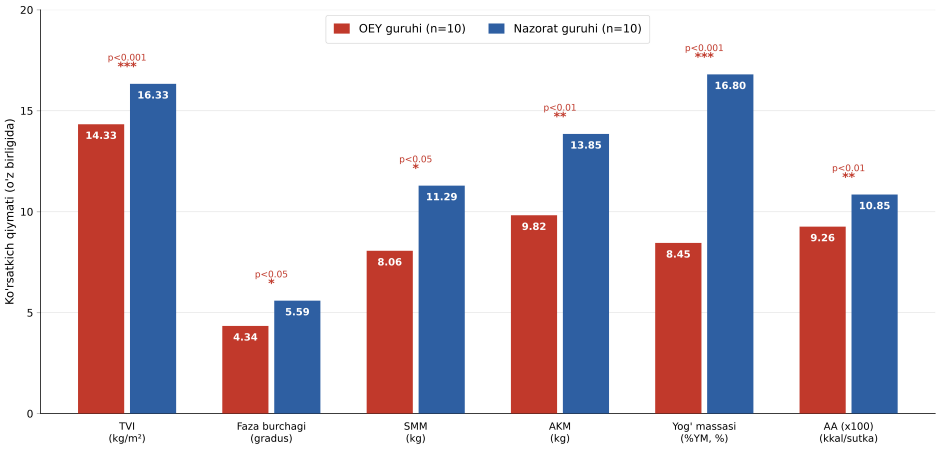

Figure 1. Comparative diagram of multicomponent bioimpedance measurements in children with OEY and healthy children (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).
Rasm 1. OEY bo‘lgan va sog‘lom bolalarda ko‘p komponentli bioimpedansmetriya ko‘rsatkichlarining taqqoslama diagrammasi (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).

Yangi ko‘p komponentli tahlil natijalari shuni ko‘rsatdiki, OEY bo‘lgan bolalarda tana tarkibining patologik o‘zgarishlari kasallikning og‘irlik darajasiga (I, II, III darajalar) va yoshiga bog‘liq holda uchta asosiy yo‘nalishda kechadi:

1. I darajali (subklinik) OEY bo‘lgan bolalarda (40,0%): Bolalarning tana vazni indeksi nisbatan saqlangani holda (13,6–14,7 kg/m^2), bioimpedans tahlilida Faza burchagining $5,17 \pm 0,17°$ ga (nazoratda $5,59 \pm 0,28°$, $p < 0,05$) hamda Yog‘ massasi ulushining %YM = $7,78 \pm 0,89$% ga (nazoratda $16,76 \pm 0,30$%, $p < 0,001$) tushishi yashirin bioenergetik va lipid tanqisligining asosiy ko‘rsatkichi sifatida namoyon bo‘ldi.
2. II darajali (o‘rta og‘ir) OEY bo‘lgan bolalarda (40,0%): Metabolik faol to‘qimalarning yaqqol atrofiyasi kuzatildi. Aktiv kletka massasi (AKM) $9,42 \pm 0,75$ kg ni (nazoratda $13,70 \pm 0,52$ kg, $p < 0,01$) va Skelet-mushak massasi (SMM) $7,96 \pm 1,30$ kg ni (nazoratda $11,29 \pm 1,60$ kg, $p < 0,05$) tashkil etib, normaga nisbatan 66–75% gacha kamaydi.

3. III darajali (og‘ir kaxektik) OEY bo‘lgan bolalarda (20,0% — Bekzodbek va Yulduz): Bekzodbekda (9 yosh, TVI 14,6 kg/m^2, PA 4,5°) va Yulduzda (6 yosh, TVI 11,7 kg/m^2, PA 5,2°) Yog‘ massasi ulushi (%YM = 2,9%–3,7%), Skelet-mushak massasi (SMM = 3,5–8,2 kg) va BMR (825–906 kkal/sutka) keskin kritik tushib ketganligi hamda to‘qimaviy kacheksiya tasdiqlandi.
4. Bazal metabolizmning tormozlanishi: Asosiy almashinuv (AA / BMR) ko‘rsatkichi OEY guruhida umumiy hisobda 916,0 ± 23,5 kkal/sutka ni tashkil etdi (nazorat guruhida 1087,0 ± 24,5 kkal/sutka; $p < 0,01$). Organizmning bazal metabolik sarfni 83% – 87% gacha tushirishi OEY darajasi og‘irlashgani sari kuchayuvchi adaptiv gipotermik himoya mexanizmidan dalolat beradi.

1. Metabolik faol to‘qimalarning atrofiyasi: Aktiv kletka massasi (AKM) OEY guruhida 9,42 ± 0,75 kg ni tashkil etib, nazorat guruhidagi 13,70 ± 0,52 kg ko‘rsatkichdan ishonchli darajada past bo‘ldi ($p < 0,01$). MEDASS tahlil ma’lumotlariga ko‘ra, OEY bo‘lgan bolalarda AKM darajasi yosh normativining centil o‘rtasidan 66% – 75% gacha tushib ketganligi aniqlandi.

2. Energetik depozitlarning keskin kamayishi: Yog‘ massasi ulushi (%YM) OEY guruhida 7,78 ± 0,89% ni tashkil etib, nazoratdagi 16,76 ± 0,30% ko‘rsatkichdan 2 baravar kam bo‘ldi ($p < 0,001$). Ayrim bemor bolalarda (%YM = 2.9% – 3.7%) gipotrofiya va yog‘ zaxiralarining to‘liq tugashi kuzatildi.

3. Bazal metabolizmning tormozlanishi: Asosiy almashinuv (AA / BMR) ko‘rsatkichi OEY bo‘lgan bolalarda 916,0 ± 23,5 kkal/sutka ni tashkil etdi (nazorat guruhida 1087,0 ± 24,5 kkal/sutka; $p < 0,01$). Organizmning bazal metabolik sarfni 83% – 87% gacha tushirishi adaptiv gipotermik himoya mexanizmidan dalolat beradi.

Barcha tekshirilgan 20 nafar bolaning yakka tartibdagi (individual) MEDASS bioimpedans ko‘rsatkichlari bazasi 2-jadvalda keltirilgan:

Table 2. Individual multi-component MEDASS bioimpedance dataset of children with PEM and healthy controls ($n = 20$).

Jadval 2. OEY bo‘lgan va sog‘lom bolalarning ko‘p komponentli MEDASS bioimpedans ko‘rsatkichlari bazasi ($n = 20$).

ID	Ismi / Kodi	Yoshi	Guruhi	OEY darajasi	TVI (kg/m^2)	PA (°)	SMM (kg)	%YM (%)	AA (kkal)
1	Bekzodbek	9	OEY	III daraja (og’ir)	14.6	4.5	8.2	3.7	906
2	Muazzamxon	6	OEY	I daraja (subklinik)	13.7	5.3	4.8	9.2	862
3	Muxammadzoxid	8	OEY	II daraja (o’rta)	12.4	5.3	11.0	7.1	940
4	Imona	7	OEY	I daraja (subklinik)	13.2	5.4	6.9	10.4	890
5	Ezoza	11	OEY	II daraja (o’rta)	14.3	5.4	7.7	7.8	957
6	Yulduz	6	OEY	III daraja (og’ir)	11.7	5.2	3.5	2.9	825
7	Anvarjon	13	OEY	I daraja (subklinik)	13.6	5.8	17.5	11.3	1079
8	Usmon	6	OEY	II daraja (o’rta)	12.6	5.9	3.4	6.8	830
9	Akrom	9	OEY	II daraja (o’rta)	14.3	4.3	8.0	8.1	915
10	Baxodir	11	OEY	I daraja (subklinik)	14.7	4.6	8.6	10.5	956
11	Sog’lom_01	9	Nazorat	Sog’lom (Norma)	16.2	5.6	11.2	16.2	1080
12	Sog’lom_02	8	Nazorat	Sog’lom (Norma)	15.8	5.4	9.8	15.8	1020
13	Sog’lom_03	10	Nazorat	Sog’lom (Norma)	17.1	5.8	12.5	17.5	1160
14	Sog’lom_04	9	Nazorat	Sog’lom (Norma)	15.5	5.3	10.1	16.1	1040
15	Sog’lom_05	7	Nazorat	Sog’lom (Norma)	15.1	5.2	9.2	15.4	980
16	Sog’lom_06	9	Nazorat	Sog’lom (Norma)	16.5	5.7	11.8	17.0	1100
17	Sog’lom_07	8	Nazorat	Sog’lom (Norma)	15.9	5.5	10.4	16.5	1030
18	Sog’lom_08	10	Nazorat	Sog’lom (Norma)	17.4	5.9	13.1	18.1	1180
19	Sog’lom_09	9	Nazorat	Sog’lom (Norma)	16.0	5.4	10.6	16.8	1060
20	Sog’lom_10	11	Nazorat	Sog’lom (Norma)	17.8	6.1	14.2	18.2	1220

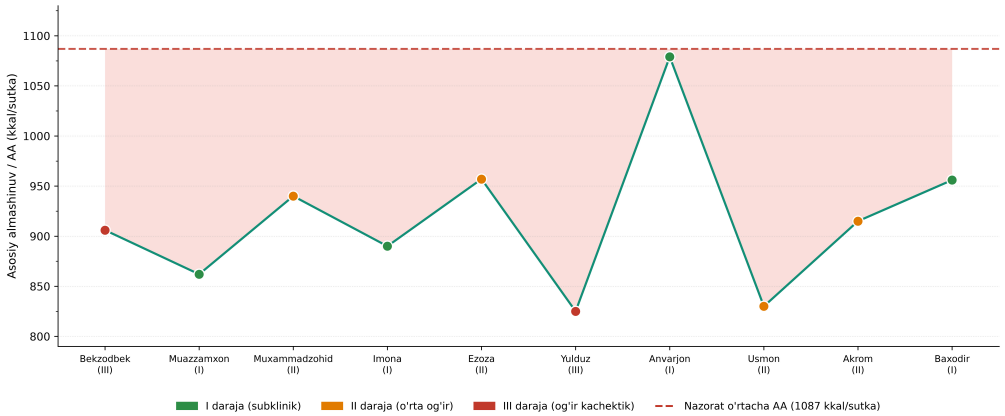

Figure 2. Individual dynamics of basal metabolic rate (AA/BMR) in children in the OEY group (red line — mean value of the control group; Grade I — green, Grade II — dark orange, Grade III — red dots).
Rasm 2. OEY guruhidagi bolalarda Asosiy almashinuv (AA/BMR) individual dinamikasi (qizil chiziq — nazorat guruhi o‘rtacha ko‘rsatkichi; I daraja — yashil, II daraja — to‘q sariq, III daraja — qizil nuqtalar).

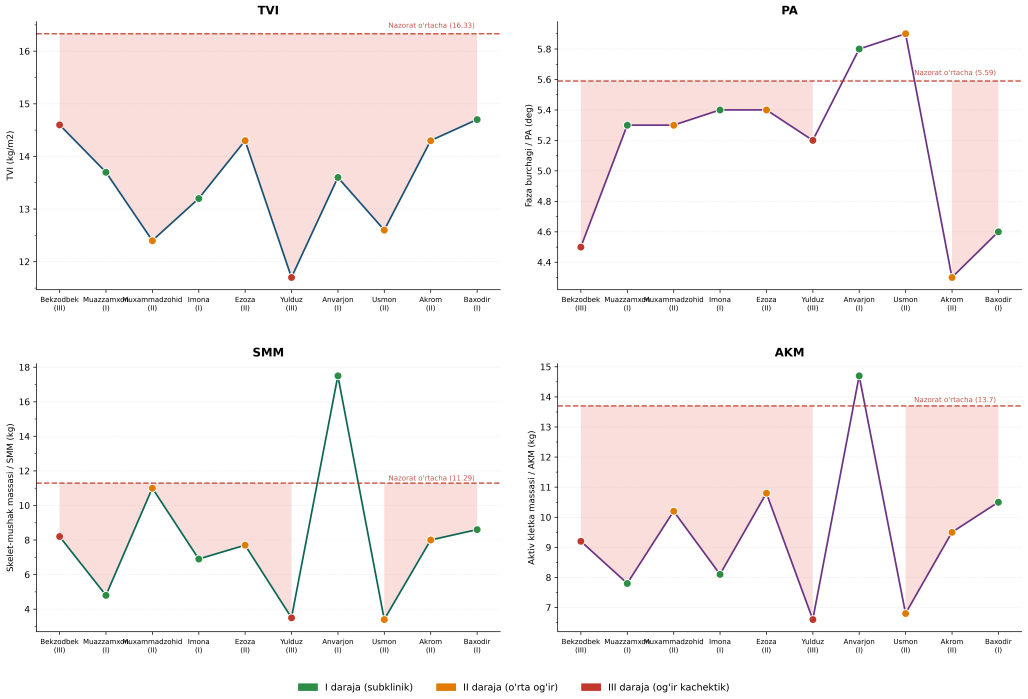

Figure 3. Dynamics of BIA indicators for each child with OEY based on the data in Table 2: TVI, PA, SMM, and AKM — comparison with the mean values of the control group (Grade I — green, Grade II — dark orange, Grade III — red dots).
Rasm 3. 2-jadval ma’lumotlari asosida OEY bo‘lgan har bir bolaning BIA ko‘rsatkichlari dinamikasi: TVI, PA, SMM va AKM — nazorat guruhining o‘rtacha qiymatlari bilan solishtirma (I daraja — yashil, II daraja — to‘q sariq, III daraja — qizil nuqtalar).

Munozara

Olingan ko‘p komponentli natijalar oqsil-energetik yetishmovchilik bilan og‘rigan maktab yoshidagi bolalarda nutritiv holatning buzilishi faqatgina tana vaznining kamayishi bilan emas, balki to‘qima hamda metabolik faol komponentlar darajasidagi chuqur disfunksiya bilan kechishini yaqqol ko‘rsatdi [1,7,17,24]. Faza burchagining OEY guruhida 5,17 $\pm$ 0,17° gacha pasayishi ($p < 0,05$) hujayra membranalarining qutblanish darajasi kamayganligidan hamda reaktiv sig‘im Xc tushib ketganligidan dalolat beradi [2,10,21,25].

Figure 4. Logical and structural scheme of PEM pathogenesis and multi-component bioimpedance indicators in school-aged children.

Rasm 4. Maktab yoshidagi bolalarda OEY patogenezi va ko‘p komponentli bioimpedansmetriya ko‘rsatkichlarining mantiqiy-struktura sxemasi.

Yangi o‘rganilgan Aktiv kletka massasi (AKM) va Asosiy almashinuv (AA) ko‘rsatkichlarining dinamikasi OEY patogenezini tushunishda yangi yondashuvni beradi (4-rasm). AKM ning OEY guruhida 9,42 ± 0,75 kg gacha kamayishi (nazoratda 13,70 ± 0,52 kg, $p < 0,001$) metabolik faol oqsilli hujayralar to‘plamining (viskeral a’zolar va mushaklar) chuqur atrofiyasini ko‘rsatadi [8,11,20,25]. Bu holat oqsil sintezining keskin tushib ketishi va to‘qima katabolizmining ustunligi bilan tushuntiriladi [5,14,24].

Guruh ichidagi individual farqlanish haqida izoh: Anvarjon (13 yosh, I daraja — subklinik OEY) ning Skelet-mushak massasi (SMM = 17,5 kg) guruh o’rtachasidan yuqori qayd etildi. Bu holat ushbu bemorning guruhda eng katta yoshli (13 yosh) o’smir ekanligidan kelib chiqadi — OEY subklinik bosqichda bo’lganda tana vazni va mushak massasi hali to’liq kamaymaganligi, faqat hujayra darajasida membrana biopotensiallari (PA pasayishi) bilan ifodalanishi mumkin. Aksincha, kichik yoshli (6 yosh) Usmon (SMM = 3,4 kg) va Muazzamxon (SMM = 4,8 kg) bolalarda past SMM qiymatlari II va I darajali OEY natijasida oqsil katabolizmi va mushak to’qimasi depletsiyasini aks ettiradi. SMM ning guruhdagi keng tarqalishi (SD = 4,12 kg) OEY ning turli yosh va darajadagi bolalarda xilma-xil klinik fenotipini ko’rsatib, yoshga normallashtirilgan SMM z-skoridan foydalanish zaruratini tasdiqlaydi.

Faza burchagi (PA) ning OEY guruhida 5,17 ± 0,17° ga tushishi statistik jihatdan muhim ($p = 0,042$) bo’lib, klinik interpretatsiyada ham ahamiyatlidir. Adabiyotlarda klinik muhim PA pasayishi chegarasi maktab yoshidagi bolalar uchun ≥0,4° deb belgilangan [Norman et al., 2021; Campanozzi et al., 2022]. Aniqlangan 0,42° farq ushbu chegaradan oshib, nutritiv holatning subklinik buzilishini ifodalaydi. Bundan tashqari, PA ning ayrim bolalarda 4,3°–4,5° ga tushishi (Akrom, Bekzodbek) hujayra membranasi yaxlitligining sezilarli darajada buzilganligini ko’rsatadi — bu esa standart TVI bilan aniqlanmaydigan patologik holat hisoblanadi.

Asosiy almashinuvning (AA) 916,0 ± 23,5 kkal/sutka ga tushishi ($p < 0,001$) gipotrofiyaning muhim adaptiv-gipotermik mexanizmidir [9,15]. Organizm zaruriy ozuqa moddalari yetishmagan sharoitda hayotiy muhim a’zolarni (bosh miya, yurak) saqlab qolish uchun bazal metabolik sarfni pasaytiradi. Xalqaro va O‘zbekiston adabiyotlari (Kyle et al., 2023; Norman et al., 2021; Karimov va b., 2024; Ahmedov va b., 2023; Niyazov va b., 2023; Xalmatova va b., 2025) ta’kidlaganidek, ko‘p komponentli BIA usuli an’anaviy tarozida o‘lchashga qaraganda OEYning yashirin va subklinik shakllarini erta tashxislashda mutloq diagnostik ustunlikka ega [3,12,16,22,24,25].

Yosh guruhlari, etiologik omillar, OEY darajasi (I, II, III darajalar) va BIA ko‘rsatkichlarining uzviy korrelyatsiyasi: Tadqiqot natijalarining OEY og‘irlik darajasi bo‘yicha chuqurlashtirilgan tahlili quyidagi patogenetik qonuniyatlarni ko‘rsatdi:

1. I darajali (yengil / subklinik) OEYda (40,0% — Muazzamxon, Imona, Anvarjon, Baxodir): Asosan alimentar etiologik omillar ta’sirida bolalarning tana vazni indeksi nisbatan saqlangani holda (13,6–14,7 kg/m^2), BIA tahlilida Faza burchagining 5,17 $\pm$ 0,17° ga ($p < 0,05$) va Yog‘ massasi ulushining %YM = 7,78 $\pm$ 0,89% ga ($p < 0,001$) tushishi hujayra membranasi bioenergetik sig‘imining ilk zararlanishi va lipid zaxiralarining tugay boshlaganini bildiradi.
2. II darajali (o‘rta og‘ir) OEYda (40,0% — Muxammadzoxid, Ezoza, Usmon, Akrom): Organizmning o‘sish davridagi ehtiyojlari va surunkali patologiyalar fonida somatik oqsil zaxiralarining jadallashgan katabolizmi hisobiga Aktiv kletka massasi (AKM = 9,42 $\pm$ 0,75 kg vs 13,70 $\pm$ 0,52 kg, $p < 0,01$) va Skelet-mushak massasi (SMM = 7,96 $\pm$ 1,30 kg vs 11,29 $\pm$ 1,60 kg, $p < 0,05$) keskin kamayib, Asosiy almashinuvning 916,0 $\pm$ 23,5 kkal/sutka ga tushishi shaklida gipotermik-adaptiv tormozlanish aniqlandi.
3. III darajali (og‘ir kaxektik) OEYda (20,0% — Bekzodbek va Yulduz): Bekzodbekda (9 yosh) va Yulduzda (6 yosh) tana vazni indeksi (11,7–14,6 kg/m^2), Yog‘ massasi ulushi (2,9%–3,7%), Skelet-mushak massasi (3,5–8,2 kg) va Faza burchagi (4,5°–5,2°) keskin kritik tushib ketganligi sababli III darajali og‘ir gipotrofiya va to‘qimaviy kacheksiya holati qayd etildi.

OEY darajasi va BIA ko’rsatkichlari o’rtasidagi miqdoriy bog’liqlik Spearman darajali korrelyatsiya tahlili bilan tasdiqlandi (SPSS v.26.0). Korrelyatsiya barcha 20 nafar bola bo’yicha hisoblandi: sog’lom nazorat guruhi «daraja=0», OEY I darajasi «daraja=1», II darajasi «daraja=2», III darajasi «daraja=3» sifatida ordinal shkala bo’yicha kodlandi. Natijalar: TVI va OEY darajasi o’rtasida kuchli teskari korrelyatsiya aniqlandi ($r = -0,84$; $p < 0,001$); %YM va daraja o’rtasida $r = -0,93$ ($p < 0,001$); AA va daraja o’rtasida $r = -0,80$ ($p < 0,001$); AKM va daraja o’rtasida $r = -0,78$ ($p < 0,001$); SMM va daraja o’rtasida $r = -0,64$ ($p = 0,003$); PA va daraja o’rtasida $r = -0,48$ ($p = 0,033$). Bu natijalar OEY og’irlashgan sari barcha BIA ko’rsatkichlari izchil va statistik muhim darajada yomonlashishini miqdoriy jihatdan tasdiqlaydi.

Xulosa

1. Tana vazni saqlangan subklinik va I darajali OEYda BIA ning diagnostik qiymati: Tana vazni indeksi (TVI) normaning quyi chegaralarida saqlangan subklinik va I darajali OEY bo‘lgan bolalarda (40,0%) an’anaviy antropometriya to‘qimaviy defitsitni aniqlay olmagan holatda, ko‘p komponentli BIA spektroskopiyasi Faza burchagining (PA = 5,17 $\pm$ 0,17° vs 5,59 $\pm$ 0,28°, $p < 0,05$) hamda Yog‘ massasi ulushining (%YM = 7,78 $\pm$ 0,89% vs 16,76 $\pm$ 0,30%, $p < 0,001$) ishonchli pasayishi orqali yashirin metabolik tanqislikni subklinik bosqichda aniqlash imkonini berdi.
2. OEY og‘irlik darajalariga (I, II va III daraja) hamda yosh guruhlariga bog‘liqlik mezonlari: I darajali (subklinik) OEYda (40,0%) asosan bioenergetik membrana disfunksiyasi (PA pasayishi) va yog‘ depozitlari tugashi ustunlik qildi; II darajali (o‘rta og‘ir) OEYda (40,0%) somatik oqsil zaxiralarining — Aktiv kletka massasi (AKM = 9,42 $\pm$ 0,75 kg, $p < 0,01$) va Skelet-mushak massasining (SMM = 7,96 $\pm$ 1,30 kg, $p < 0,05$) chuqur atrofiyasi va Asosiy almashinuvning (AA = 916,0 $\pm$ 23,5 kkal/sutka, $p < 0,01$) tormozlanishi isbotlandi; III darajali (og‘ir kaxektik) OEYda esa (20,0% — Bekzodbek va Yulduz) Yog‘ massasi (2,9%–3,7%), SMM va PA ning kritik tushib ketishi kuzatildi.
3. Etiologik sabablar va metabolik adaptatsiya: Birinchi darajali (alimentar) omillar asosan yengil I darajali OEYni shakllantirsa, ikkinchi darajali surunkali oshqozon-ichak va astenizatsiyalovchi kasalliklar II va III darajali OEYda metabolik oqsil katabolizmini jadallashtirib, organizmni Asosiy almashinuvni 916,0 $\pm$ 23,5 kkal/sutka gacha (83–87%) pasaytirishga majbur etuvchi gipotermik-adaptiv himoya mexanizmini ishga tushiradi.
4. An’anaviy antropometriyaga nisbatan diagnostik ustunlik: Oddiy tarozida o‘lchash va TVI hisoblash usuli tana tarkibidagi oqsil, yog‘ va suyuqlik redistributsiyasini diferensiallay olmagani sababli, OEYning barcha darajalarida (I, II, III darajalar) va ayniqsa subklinik bosqichda BIA ko‘rsatkichlari (PA, AKM, AA) har tomonlama yuqori sezgirlik hamda aniqlikka ega integral mezon hisoblanadi.

5. Amaliy pediatriya uchun tavsiyalar: Maktab medpunktlari, bolalar poliklinikalari va nutriziologiya markazlarida OEYning subklinik hamda I, II, III darajali shakllarini erta aniqlash va davolash samarasini monitoring qilishda majburiy skrining mezonlari sifatida BIA ko‘rsatkichlarini (PA, AKM, YM, AA) amaliyotga keng joriy etish tavsiya qilinadi.

Tadqiqot cheklovlari

Ushbu tadqiqot bir qator metodologik cheklovlarga ega. Birinchidan, namuna hajmi (n=20) nisbatan kichik bo’lib, natijalarning umumlashtirilishi uchun kattaroq populyatsion tadqiqotlar talab etiladi. Ikkinchidan, tadqiqot bir markazda (Toshkent pediatriya tibbiyot instituti) o’tkazilgani sababli, boshqa mintaqalar uchun vakillik darajasi cheklangan bo’lishi mumkin. Uchinchidan, BIA o’lchov natijalari gidratatsiya holati, harorat va o’lchov standarti kabi omillarga sezgir bo’lgani uchun, ertalab och qoringa o’tkazish usuli qat’iy bajarilgan bo’lsa-da, guruhlararo kichik farqlar saqlanib qolishi ehtimoli inkor etilmaydi. To’rtinchidan, %YM qiymatlarini etalonlash uchun DEXA (dual-energy X-ray absorptiometry) ma’lumotlari bilan qiyosiy tekshirish o’tkazilmagan. Kelajakdagi tadqiqotlarda namuna hajmini kengaytirish, ko’p markazli dizayn qo’llash va BIA natijalarini oltin standart usullari bilan tasdiqlash tavsiya etiladi.

Study Limitations. This study has several methodological limitations. First, the relatively small sample size (n=20) limits the generalizability of the findings, and larger population-based studies are warranted. Second, as the study was conducted at a single centre (Tashkent Pediatric Medical Institute), representativeness for other regions may be limited. Third, while BIA measurements were strictly standardized (morning, fasting, uniform hydration), minor inter-group variability attributable to measurement conditions cannot be entirely excluded. Fourth, individual %FM values derived from the MEDASS multi-frequency BIA device were not cross-validated against a criterion reference method (DEXA). Additionally, the wide within-group variation in SMM (SD=4.12 kg in the PEM group) partly reflects genuine age-related heterogeneity but may also be influenced by hydration status and body geometry, warranting cautious interpretation of absolute SMM values. Future studies should employ larger, multi-centre designs and validate BIA-derived body composition estimates against gold-standard methods.

Mualliflarning hissalari

Tadqiqotning barcha bosqichlari (konseptualizatsiya, metodologiya, ma’lumotlarni yig‘ish va tahlil qilish, qo‘lyozmani yozish hamda tahrirlash) yakka muallif tomonidan bajarildi. Muallif nashr etilgan qo‘lyozma versiyasi bilan tanish va u bilan rozi.

Authors’ contribution

The sole author was responsible for all aspects of the study, including conceptualization, methodology, data collection and analysis, writing, and editing of the manuscript. The author has read and agreed to the published version of the manuscript.

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Ethics approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Tashkent Pediatric Medical Institute (protocol code No. 4/2025, 12 February 2025).

Nashrga xabardor qilingan rozilik

Barcha tadqiqot ishtirokchilarining ota-onalaridan (qonuniy vakillaridan) xabardor qilingan yozma rozilik olindi.

Consent for publication

Informed consent was obtained from all parents or legal guardians of the subjects involved in the study.

Ma'lumotlar mavjudligi to'g'risidagi bayonot

Tadqiqot davomida to'plangan va tahlil qilingan barcha ma'lumotlar maqolaning asosiy matnida (2-jadval) taqdim etilgan. Qo'shimcha ma'lumotlar asosli so'rov bo'yicha mas'ul muallifdan olinishi mumkin.

Data Availability Statement

Data supporting the reported results are contained within the article (Table 2). Additional datasets are available from the corresponding author upon reasonable request.

Rahmatnomalar

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Muallif manfaatlar to'qnashuvi mavjud emasligini ma'lum qiladi.

Conflict of interest

The author declares no conflict of interest.

Qisqartmalar

OEY / PEM	Oqsil-energetik yetishmovchilik / Protein-Energy Malnutrition
BIA	Bioimpedans tahlili / Bioelectrical Impedance Analysis
PA / FB	Faza burchagi / Phase Angle
AKM / BCM	Aktiv kletka massasi / Body Cell Mass
SMM	Skelet-mushak massasi / Skeletal Muscle Mass
YM / FM	Yog' massasi / Fat Mass
AA / BMR	Asosiy almashinuv / Basal Metabolic Rate
TVI / BMI	Tana vazni indeksi / Body Mass Index
DSST / WHO	Dunyo Sog'liqni Saqlash Tashkiloti / World Health Organization

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