Received: 11 October 2023 | Revised: 21 May 2024 | Accepted: 29 May 2024

DOI: 10.1111/apa.17318

ORIGINAL ARTICLE

ACTA PÆDIATRICA NURTURING THE CHILD WILEY

Increased adiposity in juvenile idiopathic arthritis – A comparison of the bioelectrical impedance analysis and dual-energy X-ray absorptiometry for the assessment of body composition

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Funding information
The Finnish Cultural Foundation; The Foundation for Pediatric Research; Foundation of Finnish Sport Institute; Foundation of Rheumatoid Diseases; Maire Lisko Foundation

Abstract

Aim: Higher adiposity and increased risk of cardiovascular diseases have been reported in juvenile idiopathic arthritis (JIA), but body composition measurements have produced inconsistent results. This controlled cross-sectional study assessed body composition with two methods to evaluate adiposity in children with JIA.

Methods: We measured body composition by dual- energy X-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA) from 79 JIA-patients in two Finish university hospitals in 2017–2019. Their age- and sex-matched controls ($n=79$) were selected from the Physical Activity and Nutrition in Children- study and through National Registry.

Results: Body fat percentage measured by BIA was higher (mean, SD) in patients compared to controls (23.1 ± 9.3% vs. 20.1 ± 7.5%, $p=0.047$). Also, using DXA, there was a tendency of higher body fat percentage in patients (27.1 ± 9.1% vs. 24.6 ± 8.6,

Abbreviations: BIA, bioelectrical impedance analysis; BMI, body mass index; DXA, dual energy X-ray absorptiometry; JIA, juvenile idiopathic arthritis; PANIC, Physical Activity and Nutrition in Children- Study; SD, standard deviation.

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$p = 0.106$). BIA and DXA showed strong correlation (r from 0.810 to 0.977) in all body composition variables.
Conclusion: Increased adiposity was observed in patients with JIA. Evaluation of body composition should be included in the multidisciplinary care of JIA to reduce the possible risk of cardiovascular diseases in adulthood. BIA could be a useful tool for assessing body composition due to its clinical availability and safety.

KEYWORDS
adiposity, bioelectrical impedance, body composition, dual-energy X-ray absorptiometry, juvenile idiopathic arthritis

1 | BACKGROUND

Juvenile idiopathic arthritis (JIA) is the most prevalent chronic inflammatory disease in childhood, with a prevalence of 12.8–23 per 100000 population. JIA has been associated with symptoms like joint pain, stiffness, fatigue, fever, and muscle weakness, which in conjunction with medical therapy may predispose children to suboptimal nutrition, muscle weakness, mobility impairments and sedentary behaviour.[1,2] These together with silent inflammation and childhood adiposity could lead to increased risk of cardiovascular diseases in patients with JIA in adulthood.[3,4]

Previous studies on body composition in children with JIA have produced conflicting results. A systematic review concluded that it is unclear whether patients with JIA have altered body composition compared to healthy controls.[5] Some of the studies have shown that patients with JIA have higher adiposity than controls but significant association to disease activity has not been found.[6–8] Rego et al observed that adiposity, measured as BMI and fat mass, was related to increased inflammatory disease activity in JIA.[9] They found no difference in body composition between well-controlled JIA patients and those with low disability compared to healthy controls.[9]

The most frequent techniques to assess body composition are dual-energy X-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA).[10] Other techniques, such as anthropometrics and skinfolds, are not accurate enough in the evaluation of body composition.[11,12] DXA is a more exact method in assessing fat mass, especially in children with obesity.[13–15] However, it is expensive, more laborious and causes exposure to ionising radiation.[11] A segmental multifrequency bioimpedance analysis, has also shown to be a reliable and feasible method to analyse total body lean mass, and in epidemiological research, BIA has been used to assess total body composition.[13] A study in adults, found that the most accurate BIA devices evaluating body fat percentage, fat mass and fat free mass were InBody 720 and InBody 770 (Biospace, Seoul, South Korea).[16]

The design of the present study enables the comparison of DXA and BIA in assessing body composition and hence provides information on the interchangeability of the two methods. Comparing DXA and BIA, could clinically assist in selecting an appropriate and accurate body composition measurement for patients with JIA during follow-up visits, considering financial resources, safety, and feasibility. In a multidisciplinary treatment process, a finding of increased adiposity would necessitate providing the patient with more profound information on beneficial lifestyle choices, such as sports and nutrition. The primary objective of the present study was to assess the differences in body composition between patients with JIA and healthy controls. The secondary objective was to assess the consistency of DXA and BIA in the evaluation of body composition.

Key notes

- The study aimed to address the inconsistent results of body composition measurements in juvenile idiopathic arthritis (JIA) in previous studies.
- The study found that children with JIA had higher body fat percentage compared to controls, as measured by both bioelectrical impedance analysis (BIA) and dual-energy X-ray absorptiometry.
- These findings underscore the importance of evaluating body composition in patients with JIA highlighting the potential utility of BIA in clinical practice.

2 | PATIENTS AND METHODS

2.1 | Study design

This was a cross-sectional cohort study that was carried out at the Kuopio and Tampere University Hospitals in Finland.

2.2 | Participants

A total of 79 patients (33% boys, 67% girls) aged 6.8–17.5 with ongoing JIA participated in this study. Altogether, 54 patients participated in the study in the Departments of Pediatrics in Kuopio and 25 patients in Tampere University Hospitals in Finland from 2017 to 2019 and their diagnosis was set according to the International League of Association for Rheumatology criteria before the age of 16 years.[17] Children with physical or neurological disability, acute infection or a heart arrythmia such as long QT syndrome, were excluded from this study.

The control group included an age- and sex-matched control for each patient. The patients and controls were closely matched by age, with a maximum difference of 12 months. Most controls were selected from The Physical Activity and Nutrition in Children Study (PANIC), where 512 children were examined during 2007–2017. The study was registered to clinicaltrials.gov (NCT01803776).[18] The PANIC study protocol was comparable to our protocol. The PANIC study lacked children aged 11–14 years, and therefore 15 controls of this age were randomly selected through the National Registry of Finland and by public recruitment among healthy children from the same living areas as other controls.

The Research Ethics Committee, Hospital District of Northern Savo, Finland, authorised the study protocol in 2016 (authorisation number: 233/2016). The parents and age-appropriate study patients and controls provided a written informed consent.

The patients were divided into oligoarticular and polyarticular groups. Oligoarticular JIA is defined as arthritis affecting less than five joints, and polyarticular JIA as arthritis affecting five or more joints. In addition, patients were divided into active and inactive disease groups.[17] Disease activity was determined by the cut-off values of the Juvenile Arthritis Disease Activity score in 10 joints. The disease was considered active when the Juvenile Arthritis Disease Activity score in 10 joints was at least 0.6 in the oligoarthritis and at least 0.8 in the polyarthritis group, and inactive when it was less than 0.6 in the oligoarthritis and <0.8 in the polyarthritis group.[19] The Childhood Health Assessment Questionnaire was used to determine functional ability in the daily living activities of the patients.[20]

The age and gender specific BMI was calculated for each patient and control. Overweight was determined as age and gender specific BMI ≥ 25 and obesity as age and gender specific -BMI ≥ 30 using the Finnish growth references for children and adolescents.[21] The nutritional intake was analysed by a four-day food record. Physical activity, divided into active and sedentary time, was assessed for patients and controls with a validated PANIC Physical Activity Questionnaire and presented as minutes per day.[22] All investigated characteristics are shown in Tables 1 and 2.

2.3 | Body composition

2.3.1 | Dual-energy X-ray absorptiometry

Lunar Prodigy Advance Bone Densitometer (GeMedical Systems, Madison, Wisconsin, USA) was used in the assessment of body composition. DXA scanning was performed following the standard imaging and positioning. Body composition values were calculated by the software (GE-Company, Wisconsin, USA) incorporated in the densitometer. DXA is a body composition measurement method which utilises the differences in the absorption of high- and low-energy X-ray photons between lean tissue, fat tissue and bone.[23] For this study, fat mass, body fat percentage and lean mass were selected from the densitometry data. Lean mass percentage was calculated as the lean mass divided by the total body mass. In our study, lean mass was defined as lean soft tissue mass without fat or bone mass.

2.3.2 | Bioelectrical impedance analysis

BIA measures body composition by sending a small electrical current through the body, and evaluates the resistance encountered.

TABLE 1 Characteristics of patients with JIA and controls, presented as mean ± SD, unless indicated otherwise.

	JIA	Controls		Oligoarticular JIA	Polyarticular JIA	
	n = 79 Mean ± SD	*n* = 79 Mean ± SD	*p*	*n* = 21 Mean ± SD	*n* = 58 Mean ± SD	*p*
Age, years	11.7 ± 3.1	11.6 ± 3.2		11.1 ± 3.2	11.8 ± 3.1	0.352
Gender, male female	26 (32.9%) 53 (67.1%)	26 (32.9%) 53 (67.1%)		5 (23.8%) 16 (76.2%)	21 (36.2%) 37 (63.8%)	0.300
Height, cm	147.0 ± 16.1	149.4 ± 16.9	0.015	144.7 ± 17.1	147.8 ± 15.9	0.450
Weight, kg	42.7 ± 14.9	43.1 ± 14.4	0.087	39.4 ± 13.5	43.9 ± 15.3	0.235
ISO-BMI, kg/m^2	22.2 ± 3.3	21.7 ± 2.8	0.290	21.5 ± 3.2	22.4 ± 3.3	0.326
Overweight, BMI >25	15 (19.0%%)	9 (11.4%)	0.163	5 (23.8%)	10 (17.2%)	0.527
Obese, BMI >30	1 (1.3%)	1 (1.3%)	0.993	0	1 (1.7)	1.000
Physical activity, Questionnaire						
Active time, min/day	90.0 ± 43.9 *n* = 65	111.2 ± 62.2 *n* = 72	0.019	84.4 ± 44.3 *n* = 18	92.2 ± 44.1 *n* = 47	0.527
Sedentary time, min/day	431.1 ± 212.4 *n* = 68	350.7 ± 215.9 *n* = 70	0.014	426.2 ± 185.1 *n* = 18	432.9 ± 223.1 *n* = 50	0.910

Abbreviations: ISO-BMI, Age and gender-specific body mass index; JIA, Juvenile idiopathic arthritis.

TABLE 2 Disease characteristics and medication of patients with JIA, presented as mean ± SD, unless indicated otherwise.

	JIA n = 79 Mean ± SD	Oligoarticular JIA n = 21 Mean ± SD	Polyarticular JIA n = 58 Mean ± SD	p
Disease duration, years	5.6 ± 3.3	5.2 ± 3.0	5.8 ± 3.4	0.505
Active disease	39 (49%)	9 (43%)	30 (52%)	0.486
C-HAQ score, median, IQR	0 (0–0.1)	0 (0–0.2)	0 (0–0.1)	0.731
NRS pain, median, IQR	2 (0–24.0)	1 (0–18.0)	2 (0–27.8)	0.659
NRS PGA, median, IQR	0 (0–5.0)	0 (0–3.5)	0 (0–5.0)	0.740
Medication				
Cumulative total[a] corticosteroid dose 12 months, mg, median, IQR	21.0 (0–153.0)	0 (0–68.0)	52.5 (0–252.3)	0.071
Cumulative total corticosteroid dose 24 months, mg, median, IQR	116.0 (0–340.0)	40.0 (0–120.0)	169.0 (6.0–405.0)	0.020
Off medication	19 (24%)	9 (43%)	10 (17%)	
DMARDs	60 (76%)	12 (57%)	48 (83%)	0.019
Biologic DMARDs	39 (49%)	6 (29%)	33 (57%)	0.014
Synthetic DMARDs	46 (58%)	10 (48%)	36 (62%)	0.250

Abbreviations: C-HAQ, Childhood Health Assessment Questionnaire; DMARDs, Disease modifying antirheumatic drugs; JIA, Juvenile idiopathic arthritis; NRS, Numerical rating scale; PGA, Physician Global assessment of disease activity score.

[a]Intra-articular and systemic.

By analysing the resistance at different segments of the body, it provides data about the fat, muscle, and water contents in each segment.[24] In the present study, BIA was performed for 48 patients in Kuopio with InBody 720 device (Biospace, Soeul, South Korea). Since the BIA measurements of the 25 patients in Tampere were examined by a different device, their results were not included in the study analyses. The measurements were made with empty bladder. The same variables as in DXA scanning, including fat mass, body fat percentage, lean mass and lean mass percentage, were selected for further investigations.

2.4 | Statistical analyses

The statistical analyses were performed using the IBM SPSS Statistics for Windows, version 27 (IBM Corporation, New York, USA). The normality of the distribution was confirmed visually by histograms and using the Kolmogorov–Smirnov test. Depending on the normality of the distribution, variables were presented as mean ± standard deviation (SD) or median (interquartile range), and as frequencies and percentages for categorical variables. Also, we have reported the absolute difference in the mean values between the patients and the controls.

The patients, disease groups of oligoarticular, polyarticular, active or inactive disease, and controls were compared using the independent samples *t*-test, the Mann–Whitney *U*-test or the chi-square test depending on the normality of distribution. Mixed model *t*-tests were employed to compare matched pairs (patients and controls) to account for the correlations within the data. Correlates were searched for body fat percentage performed by DXA and BIA by univariate linear regression analysis. Correlations between DXA and BIA values (fat mass, body fat percentage, lean mass and lean mass percentage) were estimated by the Pearson's correlation coefficient, and scatter plot was used in graphic presentation. All differences and correlations were considered statistically significant if p value was <0.05.

3 | RESULTS

3.1 | Patient demographics

The study comprised 79 patients with JIA and 79 healthy controls. There were 18 patients with oligoarthritis, 10 patients with extended oligoarthritis, 41 patients with rheumatoid factor – negative polyarthritis, one patient with psoriatic arthritis, one patient with systemic arthritis, and two patients with undifferentiated arthritis. There were no patients diagnosed with rheumatoid factor- positive polyarthritis or enthesitis-related arthritis.

The participant characteristics of all patients, those with either polyarticular or oligoarticular disease, and controls are presented in Table 1. The 58 patients in the polyarticular and 21 patients in the oligoarticular groups were similar in age, gender, and body size.

Overweight (age and gender specific BMI ≥25) tended to be more common in those with JIA and in the polyarticular disease group, but the difference was not statistically significant.

The carbohydrate and fat intake, measured as energy percentage, did not differ between the 43 JIA patients and the 43 controls who completed the four-day food record: mean ± SD 48.5 ± 6.3 vs. 49.9 ± 5.4 (p = 0.349), mean ± SD 33.3 ± 5.6 vs. 32.0 ± 5.7, (p = 0.509), respectively. The patients with JIA had significantly less active time and more sedentary time in a day, as we have reported earlier. No such difference was found between the oligoarticular and polyarticular groups.[25]

The disease characteristics and medication of all patients with JIA and separately in the polyarticular and oligoarticular groups are presented in Table 2. A total of 39 (25%) patients had an active disease, 30 of them were in the polyarticular disease group. Statistical significance was not found in disease activity or in functional disability, determined by The Childhood Health Assessment Questionnaire (C-HAQ) between the oligoarticular and polyarticular disease groups. The polyarticular group had higher cumulative total corticosteroid dose used in the past 24 months, and also all disease modifying antirheumatic drugs and biological disease modifying antirheumatic drugs were more frequently used in this group.

3.2 | Body composition

Body composition was measured by DXA in 77 patients and 64 controls, and by BIA (InBody 720) in 48 patients and 79 controls.

3.2.1 | Dual-energy X-ray absorptiometry

There was no statistically significant difference in body composition between the patients and the controls measured by DXA. However, fat mass and body fat percentage tended to be higher (difference in means 1.50 kg and 2.45%, respectively), and lean mass and lean mass percentage lower (difference in means 0.80 kg and 2.05%, respectively) in patients with JIA than in controls. No statistically significant differences were observed between oligoarticular and polyarticular groups (Table 3). In the further analyses, body fat percentage was slightly higher in patients with inactive disease compared to controls (28.4 ± 9.6 vs 24.6 ± 8.6, p = 0.045), but no difference was observed between those with active and inactive disease (Table S1).

3.2.2 | Bioelectrical impedance analysis

Body fat percentage and fat mass were significantly higher (3.02%, 1.78 kg, respectively) in patients with JIA measured by BIA (p = 0.018, p = 0.032, respectively). In lean mass and lean mass percentage, there was a similar tendency as in DXA (difference in means between patients and controls −0.64 kg, −1.88%, respectively). No statistically significant differences were observed between the oligoarticular and polyarticular groups (Table 3), neither between those with active nor inactive disease groups, which is in line with the DXA measurements (Table S1). In the further analysis, fat mass and body fat percentage were significantly higher in patients with inactive disease compared to controls (11.77 kg vs. 9.02 kg, p = 0.040 and 24.2% vs. 20.1%, p = 0.021, respectively) (Table S1).

3.2.3 | Correlation of dual energy X-ray absorptiometry and bioimpedance measurements

To assess the interchangeability of the different body composition methods, the correlation of DXA and BIA was analysed in those subjects, 46 (58%) patients and 64 (81%) controls, who had body composition measured by both techniques (Figure S1). Population characteristics did not differ significantly in subjects measured by DXA, BIA or both (data not shown). A significant correlation between the two methods was observed in all the tested variables

TABLE 3 Body composition in patients with JIA and healthy controls, presented as mean ± SD.

	JIA Mean ± SD	Controls Mean ± SD		Oligoarticular JIA Mean ± SD	Polyarticular JIA Mean ± SD	
DXA	***n* = 77**	***n* = 64**	***p***	***n* = 21**	***n* = 56**	***p***
FM, kg	12.2 ± 7.4	10.7 ± 6.3	0.077	11.0 ± 6.1	12.7 ± 7.9	0.377
BF%	27.1 ± 9.1	24.6 ± 8.6	0.066	26.6 ± 7.6	27.3 ± 9.7	0.769
LM, kg	28.5 ± 8.7	29.3 ± 10.6	0.081	26.9 ± 8.4	29.1 ± 8.8	0.332
LM%	69.3 ± 9.0	71.4 ± 9.0	0.130	69.8 ± 7.5	69.2 ± 9.5	0.787
BIA	***n* = 48**	***n* = 79**	***p***	***n* = 12**	***n* = 36**	***p***
FM, kg	10.8 ± 7.1	9.0 ± 5.4	0.032	8.8 ± 3.4	11.5 ± 7.9	0.104
BF%	23.1 ± 9.3	20.1 ± 7.5	0.018	23.3 ± 5.9	23.1 ± 10.3	0.934
LM, kg	31.1 ± 10.3	31.7 ± 10.9	0.110	27.7 ± 11.2	32.2 ± 9.8	0.186
LM%	72.5 ± 8.9	74.3 ± 9.8	0.089	72.3 ± 5.5	72.5 ± 9.8	0.926

Abbreviations: BF%, body fat percentage; BIA, Bioelectric Impedance Analysis; DXA, Dual-energy X-Ray Absorptiometry; FM, fat mass; JIA, Juvenile idiopathic arthritis; LM%, lean mass percentage; LM, lean mass.

TABLE 4 Correlation of the body composition between DXA and BIA in patients with JIA and controls measured by both techniques.

	DXA	BIA		
n = 110	Mean ± SD	Mean ± SD	*r*	*p*[a]
FM, kg	11.3 ± 7.0	9.6 ± 6.4	0.977	<0.001
BF%	25.4 ± 9.0	21.5 ± 8.4	0.942	<0.001
LM, kg	29.2 ± 10.1	30.5 ± 10.9	0.970	<0.001
LM%	70.8 ± 9.2	73.3 ± 9.8	0.810	<0.001

Abbreviations: BF%, body fat percentage; FM, fat mass, JIA, Juvenile idiopathic arthritis; LM, lean mass; LM%, lean mass percentage.
[a]Significance of correlation between Dual-energy X-Ray Absorptiometry (DXA) and Bioelectric Impedance Analysis (BIA).

including fat mass, body fat percentage, lean mass, lean mass percentage (Table 4). The correlation was highest in fat mass ($r = 0.977$) and lowest in lean mass percentage ($r = 0.810$). The correlation of body fat percentage and lean mass percentage are presented in Figure 1. The results did not change when analysed separately in patients and controls (data not shown).

Compared to DXA, BIA yielded lower values in fat mass and body fat percentage, and higher values in lean mass and lean mass percentage, both in patients and controls (Table 4).

Multivariate analyses were not performed since in the univariate linear regression analyses, there were no significant correlations between any of the body composition parameters and age, gender, disease activity, physical activity, glucocorticoid medication, or duration of disease (data not shown).

4 | DISCUSSION

In the present study, body fat percentage measured by BIA was statistically significantly higher in patients with JIA compared to

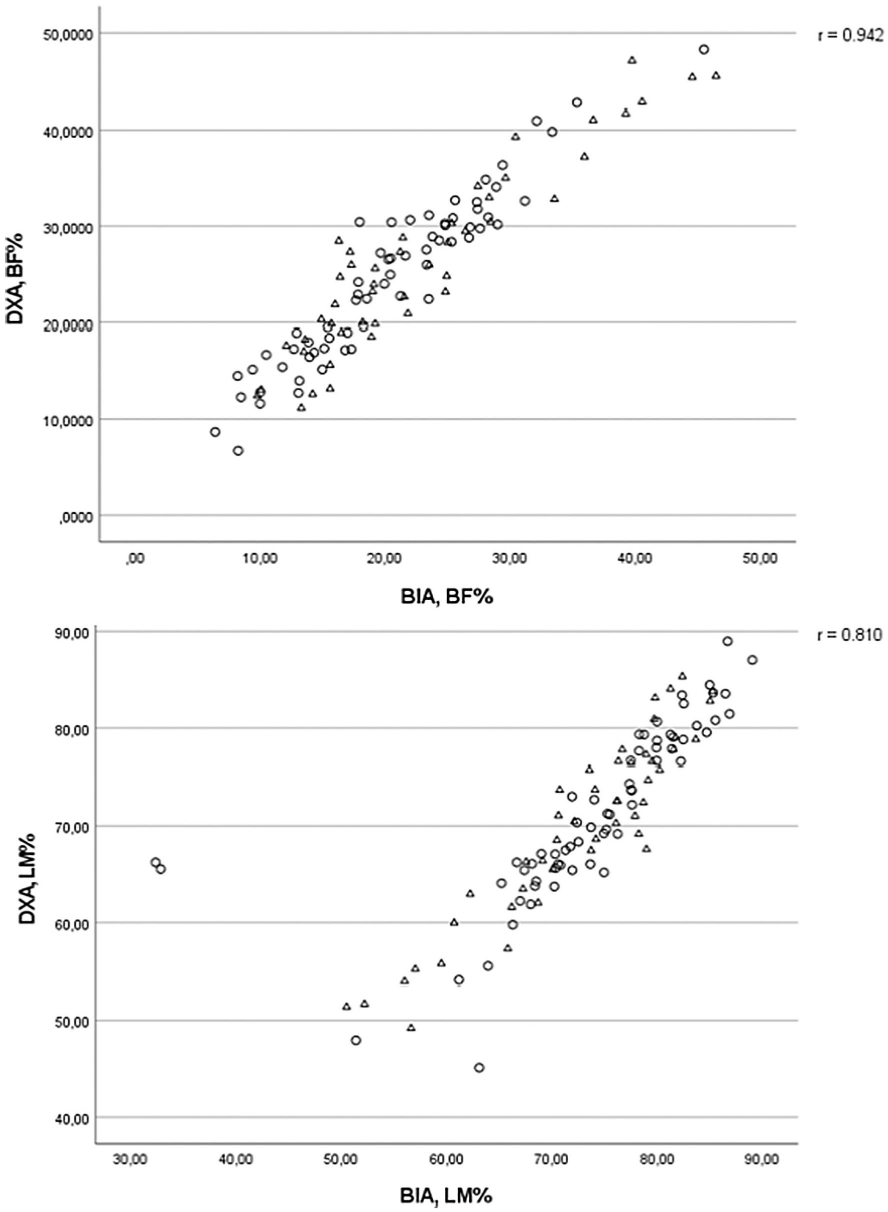

FIGURE 1 Correlation of body fat percentage measured by Dual-energy X-ray absorptiometry (DXA) and Bioelectric impedance analysis (BIA) in patients with JIA and controls (n = 110). BF%, Body fat percentage; JIA, Juvenile idiopathic arthritis; LM%, lean mass percentage.

controls. Also, in DXA, which is the gold standard for assessing body composition, there was a tendency of higher body fat percentage in patients than in controls. Childhood adiposity could lead to increased risk of cardiovascular diseases in adulthood.[26] Subclinical signs of inflammation and risk of cardiovascular diseases have been observed in adult JIA patients even in remission.[3]

Body composition assessments in JIA have produced conflicting results. High adiposity has been observed in JIA patients, both with high and low disease activity, measured by DXA and anthropometric methods.[8,27] In line with our results, a tendency of increased body fat percentage assessed by BIA was found in young patients with JIA compared to healthy controls.[1] However, in a Norwegian study, no significant difference in body fat percentage measured by DXA was observed either between the JIA patients and healthy controls, or between those with oligoarticular or polyarticular disease.[28] A Spanish study also observed no differences in fat mass (fat mass, kg/m^2) measured by DXA in patients with JIA compared to healthy peers.[9] We have earlier shown that our JIA patients were physically less active and had higher sedentary time than controls, but no such difference was found in the Norwegian study.[25] This could explain the higher adiposity in patients compared to controls in our study.

We observed no difference in body composition either between the oligoarticular and polyarticular, or between the active and inactive disease groups measured by either of the two methods. However, in the inactive disease group, body fat measured by both DXA and BIA, was significantly higher compared to controls. A similar finding has been reported in an earlier Finnish study using anthropometric measurements to assess body composition.[27] They showed that JIA patients with low inflammatory activity had more pronounced central and peripheral adiposity and overweight or obesity than healthy controls. One explanation for the higher adiposity in patients with JIA was postulated to be the higher energy intake in relation to the level of physical activity. This hypothesis was supported by our observation of the patients having similar energy intake, but lower active time and higher sedentary time in comparison with controls.

In contrast to our findings, the further analyses in the aforementioned Spanish study showed that patients with more active disease had higher fat mass compared to controls. They observed an association between increased inflammatory activity and adiposity and suggested that body composition might not be altered if the patient was under good disease control with low disability. In their study, most of the patients had an inactive disease (73%) assessed by Juvenile Arthritis Disease Activity Score in 27 joints compared to the 25% in our cohort using Juvenile Arthritis Disease Activity Score in 10 joints, which could influence the findings in the two studies. More research is needed to assess the association of inflammation, energy intake and adiposity in children with JIA.

In the present study, BIA and DXA showed strong correlation in all body composition variables including fat mass, body fat percentage, lean mass, and lean mass percentage. Previously, comparisons of DXA and BIA have been performed in healthy children and adults, and in various diseases, but not to our knowledge in patients with JIA.[28] In the cohorts of healthy children and adults, BIA and DXA showed good correlation, although BIA has underestimated fat mass and body fat percentage, and overestimated lean mass and lean mass percentage. Both have been considered precise enough methods for evaluating body composition in epidemiological studies.[13,14,29] In our study, fat mass and body fat percentage were significantly lower ($p < 0.01$) and lean mass and lean mass percentage were significantly higher ($p < 0.01$) measured by BIA compared to DXA both in patients with JIA and in healthy controls. A similar finding was shown in an Indian study, where healthy normal weight children had a significantly lower body fat percentage measured by BIA than by DXA, and lean mass was significantly higher by BIA than by DXA.[30] They found a strong correlation of body fat percentage and lean mass between DXA and BIA, in line with our study. Both methods identified normal and overweight children comparably. They suggested that when assessing body composition, BIA could be better used with the ethnic specific references. BIA underestimating fat mass has been observed also in sick children as demonstrated in a Chinese study of children with type II and III spinal muscular atrophy.[31]

4.1 | Strengths and limitations

To the best of our knowledge, this was the first study that used both DXA and BIA to investigate body composition and adiposity in patients with JIA. BIA measurements were performed by InBody720 device which has been shown to be one of the most accurate BIA devices for evaluation of body composition.[16] The same measurement protocols were used for patients and controls. All tests were performed in high-standard laboratories, by well-trained personnel, and with modern facilities. Our study benefitted from a control group that was carefully selected to match the age and sex demographics of the general population of Finnish school-aged children and adolescents. This control group was obtained from the ongoing PANIC-study cohort, and we also included healthy children selected from the National Registry and through public recruitment. Disease characteristics were evaluated by a paediatric rheumatologist, and background data were carefully collected from patient charts. The age- and sex-matched control group made possible the comparison of all study parameters with the general Finnish population of school-aged children and adolescents.

One of the limitations of this study was that both DXA and BIA InBody 720 measurement were not performed for all study patients leading to a smaller number of participants in the subgroup analyses. The study population may not have represented the total JIA population since 54% of the JIA patients treated in the Kuopio University Hospital participated. The corresponding data from Tampere were not available.[25] There were fewer patients in the oligoarticular (27%) than in the polyarticular group (73%) in our study, representing the distribution of all JIA-diagnoses in our area.

5 | CONCLUSION

Increased fat mass measured by BIA was observed in patients with JIA, and a similar tendency was also found by DXA measurements. Due to increased adiposity, evaluation of body composition should be included in the multidisciplinary care of JIA to reduce the possible risk of cardiovascular diseases in adulthood. The fat mass measured by BIA correlated strongly with the fat mass assessed by DXA, therefore BIA could be a useful tool for assessing body composition due to its clinical availability and safety. The association of adiposity, inflammation, and energy intake in children with JIA warrants further research.

AUTHOR CONTRIBUTIONS

Kati Räsänen: Writing – original draft; funding acquisition; investigation; conceptualization; methodology; writing – review and editing; data curation. **Katja Soisalo:** Investigation; writing – original draft. **Kati Markula-Patjas:** Supervision; data curation; investigation; writing – review and editing. **Saija Kantanen:** Investigation; supervision; data curation; writing – review and editing. **Kalle Sipilä:** Supervision; writing – review and editing. **Timo A. Lakka:** Supervision; resources. **Anna-Kaisa Valve-Dietz:** Methodology; writing – review and editing. **Eija Piippo-Savolainen:** Conceptualization; writing – original draft; methodology; writing – review and editing; supervision. **Pekka Arikoski:** Conceptualization; writing – original draft; methodology; writing – review and editing; supervision.

ACKNOWLEDGEMENT

We thank Panu Karjalainen, Anneli Paloranta, Heidi Lamberg and Timo Pitkänen for their contribution to the study.

FUNDING INFORMATION

The study has been financially supported by the Foundation for Pediatric Research, the Finnish Cultural Foundation, Maire Lisko Foundation, Research Foundation of Rheumatoid Diseases and Finnish Sports Academy Foundation (Suomen urheiluopistosäätiö).

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

ETHICS STATEMENT

The Research Ethics Committee, Hospital District of Northern Savo, Finland, authorised the study protocol in 2016 (authorisation number: 233/2016).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Räsänen K, Soisalo K, Markula-Patjas K, Kantanen S, Sipilä K, Lakka TA, et al. Increased adiposity in juvenile idiopathic arthritis – A comparison of the bioelectrical impedance analysis and dual-energy X-ray absorptiometry for the assessment of body composition. Acta Paediatr. 2024;00:1–9. https://doi.org/10.1111/apa.17318