Journal of Crohn's and Colitis (2012) 6, 665–673

Available online at www.sciencedirect.com

SciVerse ScienceDirect

# Lean body mass, physical activity and quality of life in paediatric patients with inflammatory bowel disease and in healthy controls

Katharina J. Werkstetter [a], Jennifer Ullrich [a], Stephanie B. Schatz [a], Christine Prell [a], Berthold Koletzko [b], Sibylle Koletzko [a,*]

[a] *Division of Paediatric Gastroenterology & Hepatology, Dr. von Hauner Children's Hospital, University of Munich Medical Center, Lindwurmstr. 4, 80337 München, Germany*

[b] *Division of Metabolic and Nutritional Medicine, Dr. von Hauner Children's Hospital, University of Munich Medical Center, Lindwurmstr. 4, 80337 München, Germany*

Received 14 July 2011; received in revised form 1 November 2011; accepted 21 November 2011

**KEYWORDS**
Physical activity;
Lean body mass;
Grip strength;
Quality of life;
Crohn's disease;
Ulcerative colitis

**Abstract**

*Background and aims:* Physical activity is important for muscle and bone strength in the growing child and may be impaired in paediatric patients with inflammatory bowel disease (IBD) even during quiescent disease. The SenseWearPro$_2$ armband allows to measure physical activity under everyday life conditions.

*Methods:* Thirty-nine IBD patients (27 Crohn's disease, 12 ulcerative colitis, 24 boys) in remission (n=26) or with only mild disease activity (n=13) were compared to 39 healthy age and sex-matched controls. Body weight, height, body mass index (BMI), lean body mass as phase angle $\alpha$ (determined by bioelectrical impedance analysis), and dynamometric grip force were expressed as age- and sex-related Z-scores. SenseWearPro$_2$ armbands were applied for three consecutive days to record number of steps, duration of physical activity and sleeping time. Quality of life was assessed with the German KINDL and IMPACT III questionnaires, energy intake with prospective food protocols. Differences between patients and pair-matched controls were analysed by paired *t*-test.

*Abbreviations* CD, Crohn's Disease; IBD, Inflammatory Bowel Disease; LBM, Lean Body Mass; MET, Metabolic Equivalent of Task; QoL, Quality of Life; UC, Ulcerative Colitis

* Corresponding author at: Division of Paediatric Gastroenterology and Hepatology, Dr. v. Haunersches Kinderspital, Ludwig-Maximilians-University of Munich, Lindwurmstraße 4, 80337 München, Germany. Tel.: +49 89 5160 7854; fax: +49 89 5160 7898.

*E-mail addresses:* katharina.werkstetter@med.uni-muenchen.de (K.J. Werkstetter), jennifer.ullrich@gmx.ch (J. Ullrich), stephanie.schatz@med.uni-muenchen.de (S.B. Schatz), christine.prell@med.uni-muenchen.de (C. Prell), berthold.koletzko@med.uni-muenchen.de (B. Koletzko), sibylle.koletzko@med.uni-muenchen.de (S. Koletzko).


doi:10.1016/j.crohns.2011.11.017

*Results:* Patients showed lower Z-scores for phase angle α (difference −0.72; 95% CI [−1.10; −0.34]) and lower grip strength (−1.02 [−1.58; −0.47]) than controls. They tended towards lesser number of steps per day (−1339 [−2760; 83]) and shorter duration of physical activity (−0.44 h [−0.94; 0.06]), particularly in females and patients with mild disease. Quality of life and energy intake did not differ between patients and controls.
*Conclusion:* In spite of quiescent disease lean body mass and physical activity were reduced. Interventions to encourage physical activity may be beneficial in this lifelong disease.


## 1. Introduction

Physical activity plays a major role in the normal development and growth during the first phase of life. Children and adolescents benefit from the effects of exercise in respect to physical fitness (cardiorespiratory efficiency, muscular strength, and endurance), bone strength, cognitive functions, and psycho-social factors (self-efficacy, self-worth and self-esteem).[1]

Reduced physical activity is a risk factor for several chronic conditions, e.g. cardiovascular diseases, diabetes or osteoporosis.[2] Low physical exercise during childhood and adolescence is associated with sedentary behaviour in adulthood and therefore may increase the risk for these negative health consequences.[3]

Children and adolescents with chronic disorders, like juvenile arthritis or asthma, are reported to be less physically active.[4] To our knowledge, no data have been published on physical activity in paediatric IBD, particularly in children with well-controlled disease. We consider it likely that physical exercise is reduced during moderate to severe disease activity or after surgery, but these are transient conditions in most patients. During remission or intervals of mild inflammation, exercise is not contraindicated[5]; though patients may tend to lower physical activity.

This study aims to answer the question whether physical activity in paediatric IBD patients is reduced compared to age- and sex-matched healthy controls even during phases of quiescent disease. Since we focused on everyday life physical activity, the SenseWear $Pro_2$ armband was applied. Furthermore, lean body mass, grip strength, mental health and quality of life were assessed to evaluate their relationship to physical activity.

## 2. Materials and methods

From October 2008 to April 2009, paediatric IBD patients were recruited at the Div. of Paediatric Gastroenterology, Dr. von Hauner Children's Hospital, University of Munich Medical Centre for the assessment of physical activity and body composition. Inflammatory bowel disease (IBD) patients were included in the study if they were between 6 and 20 years of age. The diagnosis of Crohn's disease (CD) and ulcerative colitis (UC) was established according to ESPGHAN criteria.[6] At the time of data acquisition, the patients were in remission or showed only mild disease activity for at least four weeks. Exclusion criteria were moderate to severe disease activity, hospitalization, or co-morbidities that could affect the physical activity. Forty-three eligible patients were identified. Two patients rejected participation and two were later excluded from data analysis because of occurrence of moderate disease activity during the study period, thus data of 39 patients were evaluated. The patients were pair-matched for age and sex with 39 healthy controls who were recruited from friends and schoolmates of the patients. Exclusion criteria for the control group were acute diseases e.g. infections during the last 4 weeks before the evaluation and chronic disorders or physical disabilities.

The study protocol was approved by the Local Ethical Committee of the Medical Faculty of the University of Munich. Informed consent was obtained from the parents, and from patients and controls as appropriate for their respective ages.

### 2.1. Anthropometry and grip force

Height and weight were measured, body mass index (BMI) was calculated as weight [kg] / (height [m])$^2$. Height, weight and BMI were compared with longitudinal growth reference data of German children.[7]

Bioelectrical impedance analysis was performed with a multi-channel device at 5, 50 and 100 kHz (Nutriguard M, Data Input, Darmstadt, Germany). The phase angel α was applied as a surrogate marker for the quality of lean body mass, and Z-scores were calculated based on the reference data from Bosy-Westphal et al and the Data Input compendium.[8,9]

Maximal isometric grip force of the non-dominant hand was assessed by an adjustable-handle Jamar Dynamometer (Preston, Jackson, MI). Reference data for grip force were taken from Rauch et al.[10]

### 2.2. Energy intake

The patients and controls completed a prospective dietary protocol on three consecutive days (two weekdays and one weekend day). Energy intake was calculated using the Prodi 5.2 expert software package (Nutri-Science GmbH, Freiburg, Germany) using food composition data of Bundeslebensmittelschlüssel II. The results were expressed as percentage of the daily recommended caloric energy intake for healthy children of the respective age and gender.[11]

### 2.3. Physical activity and energy expenditure

The SenseWear $Pro_2$ armband (Bodymedia Inc., Pittsburgh, Pennsylvania, USA) is a combination of a two-axial accelerometer (longitudinal and transversal) and a multisensor device, which provides additional information on skin temperature, heat flux and galvanic skin response. On the base of these measures, the analysis of the armband data is carried out by the manufacturer's software package SenseWear Professional 6.1 (Bodymedia Inc., Pittsburgh, Pennsylvania, USA). It provides several parameters: the total metabolic equivalent of task (METs) [kcal per kg body weight per hour] is an important raw value. The total energy expenditure in kcal per day can be calculated by the multiplication of the average daily METs*kg body weight*24 h. However, since the total energy expenditure in kcal depends on body weight, we exclusively used the average METs as a surrogate marker for the total energy expenditure. Furthermore, the daily number of steps, the duration of total physical activity (defined as activities with an energy expenditure of ≥3 METs), the lying down duration and the sleep duration were recorded. Activity levels ranging from 3 to 6 METs were arbitrarily considered as moderate and those >6 as high physical activity, based on Ainsworth et al.[12]

The armband was worn consecutively for 72 h (2 weekdays, 1 day at the weekend, and parallel to the dietary protocol) on the right upper arm (regardless of the patient's handedness) over the triceps brachii muscle mid way between the acromion and the olecranon. Patients were instructed to wear the armband continuously and only to remove it during the time period when they were having a shower or a bath. Only armband records with a recording time of ≥95% were considered. Due to technical problems, recordings were repeated in one patient and two controls.

## 2.4. Quality of life

The quality of life (QoL) was assessed by the German KINDL questionnaire, which is subdivided in three different age groups: the Kiddy-KINDL for children between 4 and 7 years of age, the Kid-KINDL for the age group 8 to 11 years and the Kiddo-KINDL for children and adolescents aged 12 years and older.[13]

Each version consists of 24 Likert-scaled items, which are subdivided in six dimensions (subscales) of quality of life: physical well-being, emotional well-being, self-worth, well-being in the family, well-being regarding friendships and well-being at school. The score of each item ranges from 1 (never) to 5 (always), while the total of the subscales and the overall score are calculated from the items' means. The raw scores are transformed into a 0–100 scale. Higher scores indicate a better QoL.

Only the patients were asked to complete the IMPACT III, which is a specific health related quality of life questionnaire for children and adolescents with IBD.[14] It consists of 35 questions, subdivided in six different subscales: bowel symptoms, systemic symptoms, emotional functioning, social functioning, body image, and treatment. The Likert-scaled questionnaire offers 5 response options for each item. Higher scores indicate a better disease-related QoL. Results for the total score and each subscale are expressed as percentage of the maximal possible points.

## 2.5. Patient related parameters

The following IBD-related parameters were assessed in patients only. The Montreal classification was applied for localisation, behaviour and severity of the disease.[15] To assess the disease activity, we calculated the Paediatric Crohn's Disease Activity Index (PCDAI) in CD patients and the Paediatric Ulcerative Colitis Activity Index (PUCAI) in UC patients.[16,17] Remission was considered if the scores were lower than 10, mild disease activity was defined as a PCDAI Score from 10 and 27.5 and a PUCAI Score from 10 to 34. Drug therapy included mesalazine, sulfasalazine, azathioprine, systemic glucocorticoids and anti-TNF-α-antibodies (Infliximab). The current dose of corticosteroids was recorded at the time of measurement and the cumulative lifetime dose (in mg prednisone equivalent) was calculated. Enteral nutrition therapy was defined as exclusive enteral feeding with a balanced formula for at least 4 weeks. Biochemical parameters involve haemoglobin (Hb) [g/dl], albumin [g/dl], C-reactive protein [CRP] and erythrocyte sedimentation rate [ESR].

## 2.6. Statistics

Sex-, age- and height-specific Z-scores were calculated using the formula:

Z-score = [(test result for a patient) − (age and sex-specific mean in reference population)] / (age and sex-specific standard deviation in reference population).

Normal distribution was visually checked by histograms and tested by Kolmogorov–Smirnov. The paired samples *t*-test was applied to analyse differences between patients and controls. Mean and 95% CI were indicated. Since the results for neither the quality of life scores nor their differences were normally distributed, the Wilcoxon rank-sum test was calculated and median and lower and upper quartiles were indicated. Tests for differences between patients and controls were also stratified by gender, by type of diagnosis and by disease activity (remission and mild disease). 2-factorial ANOVA was applied to test for effect-modification between subgroups. All tests were two tailed, p-values ≤ 0.05 were considered significant. Statistical analyses were performed by using the software package PASW Statistics, release 18.0 (SPSS Inc., Chicago, Illinois, USA).

# 3. Results

All 78 participants completed the protocol. The mean age of the 39 patients (27 CD, 24 males) was 15.1 ± 2.9 years (mean ± SD, range 7.8–19.3 years) and of the 39 controls 15.2 ± 3.1 years (range 8.3–20.0). Ileocolonic localisation was observed in 22 of 27 CD patients, ileal localisation only in 2 and colonic only in 3 patients. Ten of the 12 UC patients had pancolitis, one patient had proctitis and the remaining child left sided colitis. The patients' data on disease activity indices, medical and nutritional therapy, and biochemical markers are summarized in Table 1, separated by type of disease (CD or UC). At time of data recording, only one patient with UC was on glucocorticosteroid therapy (8 mg prednisolon per day). According to the PCDAI and the PUCAI, two thirds of each disease group were in remission and one third had mild disease activity.

**Table 1** Age, disease duration and activity, medication, nutritional therapy and biochemical parameters of all patients, subdivided according to subtype of IBD; median (range) respectively frequency were indicated.

| | Crohn's disease (n=27) | Ulcerative colitis (n=12) | All patients (n=39) |
|---|---|---|---|
| Age at diagnosis [y], median (range) | 10.9 (4.7–16.8) | 11.7 (7.4–17.3) | 11.5 (4.7–17.3) |
| Disease duration [y], median (range) | 3.2 (0.2–12.6) | 3.1 (0.6–8.1) | 3.5 (0.2–12.6) |
| PCDAI (only CD) [a] | | | |
| – Remission [n] (range) | 18 (0–7.5) | | |
| – Mild activity [n] (range) | 9 (10–15) | | |
| PUCAI (only UC) [a] | | | |
| – Remission [n] (range) | | 8 (0–7.5) | |
| – Mild activity [n] (range) | | 4 (10–30) | |
| Medication | | | |
| 5-ASA [n] | 21 | 8 | 29 |
| Sulfasalazine [n] | 5 | 3 | 8 |
| Azathioprine [n] | 19 | 9 | 28 |
| Infliximab [n] | 8 | 1 | 9 |
| Glucocorticoids ever [n] | 12 | 12 | 24 |
| Glucocorticoids lifetime dose min–max [mg] | 530–15673 | 1157–10567 | 530–15673 |
| Nutritional therapy (≥4 weeks, only CD, n=27) | | | |
| Patients with present nutritional therapy [n] | 5 | – | 5 |
| Patients with nutritional therapy ever [n] | 20 | – | 20 |
| Biochemical parameters, median (range) | | | |
| Haemoglobin [g/dl] | 12.8 (11.4–17.0) | 14.0 (11.6–15.8) | 13.0 (11.4–17.0) |
| Albumin [g/dl] | 4.6 (3.6–5.3) | 4.7 (4.1–5.2) | 4.6 (3.6–5.3) |
| CRP [mg/dl] | 0.24 (0.1–2.9) | 0.10 (0.1–1.1) | 0.17 (0.1–2.9) |
| ESR [mm/h] | 13 (3–62) | 16 (1–49) | 14 (1–62) |

[a] Normative data for disease activity indices: PCDAI <10=remission, 10–27.5=moderate, 30–37.5=mild, ≥40=severe disease activity; PUCAI <10=remission, 10–34=mild, 35–64=moderate, and ≥ 65=severe.

### 3.1. Anthropometric data and grip strength

The Z-scores for height, weight, BMI, phase angle α and grip strength, separated for patients and controls, and the mean differences of the Z-scores between the matched pairs are shown in Table 2. Patients showed significantly lower Z-scores than controls for all parameters (all $p \leq 0.015$, pair-matched *t*-test). The results were comparable when crude data were used instead of Z-scores (data not shown).

While separate analysis for Z-score differences between CD patients and controls showed significant negative results (all $p \leq 0.021$), CU patients did not differ from their healthy matches in height, weight, BMI and grip strength, but phase angle α was also reduced ($p = 0.002$) (Table 3). Similarly, female patients only differed significantly from their healthy control in phase angle α Z-scores ($p = 0.018$), but males in all parameters (all $p \leq 0.013$). A possible effect-modification between sex and type of diagnosis was precluded by two-factorial ANOVA.

**Table 2** Data on anthropometrics, physical activity and energy intake for patients and controls, and differences between the age- and sex-matched pairs; means and 95% CI are indicated.

| | Patients (n=39) (Mean, 95% CI) | Controls (n=39) (Mean, 95% CI) | Pair-matched differences (n=39) (Mean, 95% CI) |
|---|---|---|---|
| Height Z-score | −0.54 [−0.84; −0.24] | 0.18 [−0.12; 0.47] | −0.72 [−1.14; −0.30] |
| Weight Z-score | −0.75 [−1.04; −0.46] | −0.35 [−0.31; 0.23] | −0.71 [−1.08; −0.34] |
| BMI Z-score | −0.56 [−0.83; −0.28] | −0.15 [−0.39; 0.10] | −0.41 [−0.74; −0.08] |
| Grip force Z-score (n=32) | −0.34 [−0.72; 0.42] | 0.83 [0.41; 1.24] | −1.02 [−1.58; −0.47] |
| Phase angle α Z-score (n=38) | −0.64 [−0.95; −0.34] | 0.09 [−0.16; 0.35] | −0.72 [−1.10; −0.34] |
| Number of steps | 9828 [8937; 10,718] | 11,166 [10,060; 12,272] | −1339 [−2760; 83] |
| Duration of physical activity [h] (>3 METs) | 2.29 [1.96; 2.63] | 2.74 [2.33; 3.14] | −0.44 [−0.94; 0.057] |
| – Moderate (3–6 METs) | 2.01 [1.71; 2.31] | 2.36 [1.97; 2.76] | −0.35 [−0.79; 0.09] |
| – High (> 6 METs) | 0.28 [0.20; 0.36] | 0.42 [0.29; 0.54] | −0.14 [−0.28; 0.00] |
| Lying down duration | 9.10 [8.75; 9.46] | 8.70 [8.30; 9.09] | 0.41 [−0.04; 0.85] |
| Sleeping duration | 7.14 [6.80; 7.48] | 6.73 [6.40; 7.06] | 0.41 [−0.02; 0.85] |
| Mean METs [kcal/h/kg body weight] | 1.66 [1.60; 1.72] | 1.73 [1.65; 1.80] | 0.06 [0.03; 0.81] |
| Energy intake [in % of daily recommendation] | 80.0 [73.1; 86.8] | 85.9 [80.4; 91.4] | −5.9 [−16.0; 4.2] |

**Table 3** Differences between the age-and sex-matched pairs for anthropometrics, physical activity and energy intake, stratified by sex, type of diagnosis and disease status (remission or mild disease); means and 95% CI are indicated.

| | Differences between patients and pair-matched controls | | | | | |
|---|---|---|---|---|---|---|
| | Boys (n=24) | Girls (n=15) | CD (n=27) | UC (n=12) | Patients in remission (n=26) | Patients with mild disease activity (n=13) |
| Height Z-score | −0.77 [−1.35; −0.19] | −0.64 [−1.31; 0.03] | −0.96 [−1.47; −0.45] | −0.18 [−0.94; 0.59] | −0.51 [−0.98; −0.04] | −1.15 [−2.05; −0.25] |
| Weight Z-score | −0.92 [−1.45; −0.39] | −0.37 [−0.86; 0.12] | −0.81 [−1.20; −0.43] | −0.48 [−1.43; 0.47] | −0.50; [−0.93; −0.08] | −1.13 [−1.87; −0.38] |
| BMI Z-score | −0.63 [−1.09; −0.16] | −0.06 [−0.49; 0.36] | −0.37 [−0.60; −0.06] | −0.51 [−1.42; 0.41] | −0.33 [−0.69; 0.19] | −0.57 [−1.34; 0.20] |
| Grip force Z-score | −1.40 [−2.14; −0.67] | −0.54 [−1.43; 0.35] | −1.27 [−1.96; −0.57] | −0.49 [−1.53; 0.54] | −0.94 [−1.65; −0.23] | −1.19 [−2.25; −0.13] |
| Phase angle $\alpha$ Z-score | −0.54 [−0.94; −0.13] | −1.04 [−1.86; −0.21] | −0.57 [−1.08; −0.06] | −1.05 [−1.61; −0.49] | −0.40 [−0.84; 0.04] | −1.34 [−2.01; −0.66] |
| Number of steps | −1208 [−3089; 672] | −1547 [−3994; 900] | −1515 [−3133; 104] | −943 [−4220; 2334] | −1041 [−2862; 780] | −1934 [−4495; 628] |
| Duration of physical activity [h] (>3 METs) | −0.19 [−0.87; 0.49] | −0.84 [−1.59; −0.09] | −0.14 [−0.65; 0.38] | −1.12 [−2.29; 0.046] | 0.23 [−0.83; 0.38] | −0.86 [−1.82; 0.09] |
| – Moderate (3–6 METs) | −0.15 [−0.76; 0.46] | −0.68 [−1.34; −0.03] | −0.07 [−0.51; 0.36] | −0.98 [−2.05; 0.09] | −0.22 [−0.81; 0.37] | −0.62 [−1.32; 0.07] |
| – High (>6 METs) | −0.12 [−0.31; 0.07] | −0.16 [−0.39; 0.06] | −0.07 [−0.22; 0.08] | −0.29 [−0.62; 0.03] | −0.09 [−0.22; 0.05] | −0.24 [−0.59; 0.11] |
| Lying down duration [h] | 0.42 [−0.08; 0.91] | 0.39 [−0.55; 1.33 ] | 0.29 [−0.28; 0.86] | 0.67 [−0.12; 1.45] | 0.14 [−0.36; 0.64] | 0.94 [0.09; 1.87] |
| Sleeping duration [h] | 0.42 [−0.06; 0.89] | 0.39 [−0.52; 1.29] | 0.44 [−0.10; 0.99] | 0.33 [−0.47; 1.12] | 0.12 [−0.40; 0.63] | 0.99 [0.24; 1.74] |
| Mean METs [kcal/h/kg body weight] | −0.04 [−0.16; 0.09] | −0.11 [−0.24; 0.18] | −0.03 [−0.11; 0.06] | −0.16 [−0.39; 0.07] | −0.02 [−0.12; 0.08] | −0.17 [−0.35; 0.02] |
| Energy intake [in % of daily recommendation] | −1.6 [−15.1; 11.9] | −12.8 [−29.1; 3.5] | −8.9 [−20.8; 2.8] | 1.0 [−20.7; 22.6] | 0.7 [−10.6; 12.2] | −19.3 [−39.4; 0.9] |

Stratified for disease activity, there was a trend towards lower phase angle α Z-scores for patients in remission compared to controls ($p = 0.075$), while a significant difference was detected for patients with mild disease activity ($p = 0.001$). The phase angel alpha as indicator for lean body mass correlated with the grip strength ($r = 0.60$, $p < 0.001$ overall and $r = 0.57$, $p < 0.001$ for patients).

## 3.2. Energy intake

Overall, patients and controls did not differ in energy intake expressed as % of the daily reference intakes for age and gender. However, patients with mild disease activity tended towards a lower energy intake (−19.3 %) than their matched controls ($p = 0.059$).

## 3.3. Physical activity and energy expenditure

The differences in duration of physical activity and number of steps between patients and controls did not reach significance. However, a strong trend was noticed especially for a reduced duration of high-level physical activity ($p = 0.051$) in patients and also for the number of steps ($p = 0.064$); in contrast, sleep duration seemed to be prolonged ($p = 0.061$) (Table 3).

Stratified for the type of disease, the differences between healthy controls and both CD or UC patients were not significant. However, UC patients tended towards a shorter duration of physical activity ($p = 0.058$) and CD patients towards less number of steps ($p = 0.065$). Female patients had a significantly shorter duration of physical activity (in total and on a moderate level) than their matched controls ($p = 0.03$ and $p = 0.042$) (Fig. 1); male patients showed a trend towards a longer sleep duration ($p = 0.081$). In patients with mild disease activity, a trend towards lower duration of physical activity ($p = 0.075$) (Fig. 2) and significantly prolonged sleep duration ($p = 0.014$) were detected, while there were no significant differences between the patients in the remission group and their respective controls. There was no effect-modification between sex and disease activity status.

## 3.4. Quality of life

Overall and in the stratified analyses, patients and controls did not differ in the scores of the KINDL questionnaire (data not shown). The scores of the IBD-specific IMPACT III were as follows (median and lower and upper quartiles): total score 83 (range 79–87), bowel symptoms 86 (80–91), systemic symptoms 80 (80–93), emotional functioning 80 (69–89), social functioning 87 (83–92), body image 80 (67–87), and treatment 80 (67–87). No significant correlation was found between physical activity and the KINDL score or the health related quality of life score of the IMPACT III (patients only).

# 4. Discussion

Our study reveals that children and adolescents with well-controlled IBD show lower physical activity, particularly in girls and in patients with mild disease activity. Although the difference just missed statistical significance in the moderate number of patients studied, the effect size of the observed trend seems clinically relevant with much less steps taken per day (~1000 in patients in remission and ~2000 in mild disease) and almost half an hour less physical activity per day, and ~30 min more sleeping time. Even a mild disease activity appeared to have a marked effect on

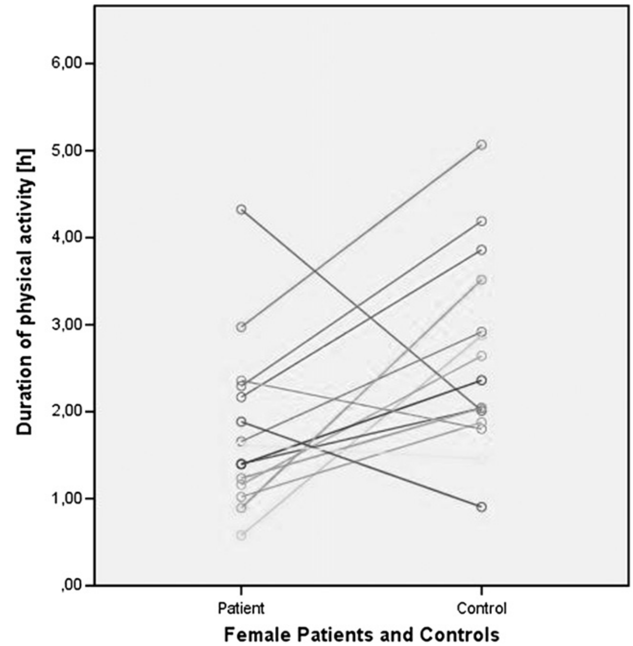


**Figure 1** Duration of physical activity in female patients compared to their age- and sex-matched controls.

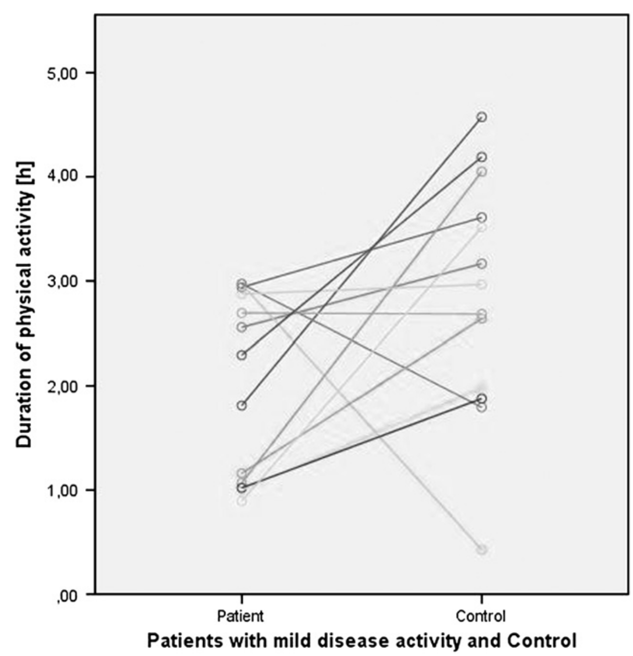


**Figure 2** Duration of physical activity in patients with mild disease activity compared to their age- and sex-matched controls.

these parameters compared to quiescent disease. To our knowledge, our data present the first evaluation on physical activity and sleeping duration in paediatric IBD applying a multisensory accelerometer during normal daily life conditions.

In accordance with publications on other paediatric IBD cohorts,[18–21] our patients had reduced Z-scores for height, weight and BMI; this was particularly marked in males and in CD patients. Body composition, especially lean body mass (LBM), may reflect the nutritional situation more accurately than BMI. Reduced LBM and reduced muscle mass have already been described in paediatric IBD patients[22–25] and may have negative long-term effects on the physical fitness and the bone health.[26,27] We assessed LBM by bioelectrical impedance phase angle $\alpha$. This parameter is a raw value, therefore independent of weight and less prone to assumptions used for calculation of LBM and other parameters.[28] In all subgroups, the phase angle $\alpha$ Z-scores were lower in the patients than in the controls indicating a reduced LBM even in patients in remission. The reduced dynamometric grip force over all patients and in particular for males and CD patients reflects the functional deficits of the muscle mass. This finding supports the assumption that a low phase angel $\alpha$ indicates decreased LBM. In a longitudinal cohort study with CD children, BMI and clinical symptoms improved two years after initial diagnosis, but initially low LBM did not.[26] It was reported that inflammation, glucocorticosteroid therapy, anorexia and malnutrition contribute to the loss of LBM respectively muscle mass in patients with CD and UC.[24] Besides treatment and nutritional effects, physical activity may play a key role to regain and maintain the musculature in children and adolescents with IBD. Our results indicate that IBD patients seem to change their lifestyle resulting in less steps and sportive activities even during phases of remission.

In our cohort, the SenseWear $Pro_2$ armband was applied to assess physical activity and energy expenditure. The armband was validated in children and adolescents against indirect calorimetry; however, it tends to overestimate low levels and underestimate high levels of physical activity.[29,30] For our data, these limitations have only a minor impact, since we compared patients with healthy age- and sex-matched controls using the same method. The advantage of the armband over indirect calorimetry is its applicability under daily life condition. Our data failed to reach an overall statistical significance, presumably due to an underpowered sample size even though we recruited a sizeable number of children with quiescent disease into this study. However, we found a strong trend towards reduced general physical activity in patients compared to healthy controls, as indicated by a lesser number of steps and a shorter duration of physical activity. This is most pronounced in girls with significant shorter physical activity duration in total and on a moderate level compared to their controls. Reduced physical activity may negatively affect the health status of the IBD patients in several ways. The general fitness is likely to be impaired, which may not only result in reduced physical condition, functional ability and motor skills; the risk for several health problems associated with hypoactivity, e.g. cardiovascular conditions, or type 2 diabetes, may also increase.[4] Impaired bone density in paediatric patients and increased risk for osteoporosis in adults are already a well-known problem in IBD.[22,25,31] Several reviews emphasize the major role of muscle and physical activity on bone growth and strength in healthy children and adolescents, particularly during puberty.[2,32–35] The bone remodelling mechanism hypothesis suggests that physical activity influences bone metabolism both directly and indirectly by muscle innervations via mechanical loads. If these dynamic strains exceed an upper threshold, an interstitial fluid flow mediates the mechanical signals to osteoblasts, which induce bone formation.[32,36] Weight-bearing activities like gymnastics, running or jumping activities induce high dynamic loads and therefore enhance bone formation.[37] The impact of an increase in physical activity on the bone strength of paediatric IBD patients had not been examined yet. One prospective randomized controlled intervention study investigated the effects of a home-based low-impact exercise program in 107 adult CD patients and reported positive effects on the bone density in the exercise group.[38] Since the highest capacity to maximize bone strength appears to exist in the pre- and peripubertal phase, this window of opportunity should be exploited in paediatric IBD, in addition to an adequate pharmacological and nutritional therapy.

In addition to positive effects on physical condition, exercise may also benefit mental health. Improved cognitive development and psycho-social factors like self-esteem and quality of life are described.[39,40] The latter is frequently impaired in children and adolescents with IBD.[41] We found no difference between patients and controls in QoL as assessed by the KINDL questionnaire. The results of the paediatric IBD-specific Impact III questionnaire support a good QoL in the majority of our patients and reflect the well-controlled disease activity.[14] Since we included only patients with quiescent disease, no significant relation was found between inflammatory markers such as CRP and QoL or physical activity. This is in contrast to studies in adult IBD patients with a larger range of disease severity which reported an association between physical activity and inflammatory markers or disease activity, respectively,[42.40] However, evidence is lacking that physical activity itself has an impact on the inflammatory process, and reverse causality appears to be the most likely explanation for their finding. In our patient group we did not find any significant relation between physical activity and QoL score. However, our study design does not allow final conclusion regarding the relation of physical activity and mental health and QoL in paediatric IBD patients. IBD patients tend to dissimulate and underreport symptoms. Therefore, a prospective randomized controlled intervention trial with an intra-individual comparison before and after an intervention program and no intervention may be more appropriate to investigate the impact of increased physical activity on the different outcome parameters.

In conclusion, we found significantly reduced lean body mass, a trend towards low physical activity and normal quality of life in paediatric IBD patients with well-controlled disease activity, compared to age- and sex-matched controls. Since physical exercise and muscle mass play a major role in the physical and mental development of growing children and adolescents and may have long-term effects on health and well-being, an enhanced physical activity in addition to the inflammatory and nutritional management might improve the situation of these patients. To test this hypothesis, a prospective randomized controlled intervention study with long-term follow up should examine the effects of physical activity on muscle mass and general physical health, especially on bones, and on mental conditions.

## Specific author contributions

Katharina J. Werkstetter: study concept and design, recruitment of participants, aquisition of data, statistical analyses, interpretation of data, writing of the manuscript
Jennifer Ullrich: recruitment of participants, acquisition of data, interpretation of data
Stephanie B. Schatz: acquisition of data, revision of the manuscript
Christine Prell: acquisition of data, revision of the manuscript
Berthold Koletzko: critical revision of the manuscript, raising funding support
Sibylle Koletzko: study concept and design, interpretation of data, revision of the manuscript, study supervision, raising funding support

## Financial support

Financially supported in part by the Competence Network Obesity, funded by the German Federal Ministry of Education and Research Grant No. 01GI0825. BK is the recipient of a Freedom to Discover Award of the Bristol Myers Squib Foundation, New York, NY, USA.

## Potential competing interests

None.

## References

1. Tomporowski PD, Lambourne K, Okumura MS. Physical activity interventions and children's mental function: an introduction and overview. *Prev Med* 2011;**52**(Suppl 1):S3–9.
2. Hallal P, Victora C, Azevedo M, Wells J. Adolescent physical activity and health. *Sports Med* 2006;**36**:1019–30.
3. Telama R. Tracking of physical activity from childhood to adulthood: a review. *Obes Facts* 2009;**2**:187–95.
4. van Brussel M, van der Net J, Hulzebos E, Helders PJ, Takken T. The Utrecht approach to exercise in chronic childhood conditions: the decade in review. *Pediatr Phys Ther* 2011;**23**:2–14.
5. Loudon CP, Corroll V, Butcher J, Rawsthorne P, Bernstein CN. The effects of physical exercise on patients with Crohn's disease. *Am J Gastroenterol* 1999;**94**:697–703.
6. Working IBD. Group of the European Society for Paediatric Gastroenterology, Hepatology and Nutrition et al. Inflammatory Bowel Disease in Children and Adolescents: Recommendations for Diagnosis-The Porto Criteria. *J Pediatr Gastroenterol Nutr* 2005;**41**:1–7.
7. Kromeyer-Hauschild K, Wabitsch M, Kunze D, et al. Perzentile für den Body-mass-Index für das Kindes- und Jugendalter unter Heranziehung verschiedener deutscher Stichproben. *Monatsschr Kinderheilkd* 2001;**149**:807–18.
8. Bosy-Westphal A, Danielzik S, Dörhöfer R, et al. Phase angle from bioelectrical impedance analysis: population reference values by age, sex, and body mass index. *J Parenter Enter Nutr* 2006;**30**:309–16.
9. Dörhöfer R, Pirlich M. Das BIA-Kompendium. Data Input GmBH, 3rd ed.; 2007.
10. Rauch F, Neu CM, Wassmer G, et al. Muscle analysis by measurement of maximal isometric grip force: new reference data and clinical applications in pediatrics. *Pediatr Res* 2002;**51**:505–10.
11. DGE. D-A-CH Referenzwerte für die Nährstoffzufuhr. 1st ed. Frankfurt am Main: Umschau/Braus GmbH, Verlagsgesellschaft; 2000.
12. Ainsworth BH, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000;**32**(Suppl 9):S498–504.
13. Ravens-Sieberer U, Bullinger M. Assessing health-related quality of life in chronically ill children with the German KINDL: first psychometric and content analytical results. *Qual Life Res* 1998;**7**:399–407.
14. Otley A, Smith C, Nicholas D, et al. The IMPACT questionnaire: a valid measure of health-related quality of life in pediatric inflammatory bowel disease. *J Pediatr Gastroenterol Nutr* 2002;**35**:557–63.
15. Satsangi J, Silverberg MS, Vermeire S, et al. The Montreal classification of inflammatory bowel disease: controversies, consensus, and implications. *Gut* 2006;**55**:749–53.
16. Hyams J, Ferry GD, Mandel FS, et al. Development and validation of a pediatric Crohn's disease activity index. *J Pediatr Gastroenterol Nutr* 1991;**12**:439–47.
17. Turner D, Otley AR, Mack D, et al. Development, validation, and evaluation of a pediatric ulcerative colitis activity index: a prospective multicenter study. *Gastroenterology* 2007;**133**:423–32.
18. Hildebrand H, Karlberg J, Kristiansson B. Longitudinal growth in children and adolescents with inflammatory bowel disease. *J Pediatr Gastroenterol Nutr* 1994;**18**:165–73.
19. Markowitz J, Grancher K, Rosa J, et al. Growth failure in pediatric inflammatory bowel disease. *J Pediatr Gastroenterol Nutr* 1993;**16**:373–80.
20. Pfefferkorn M, Burke G, Griffiths A, et al. Growth abnormalities persist in newly diagnosed children with Crohn disease despite current treatment paradigms. *J Pediatr Gastroenterol Nutr* 2009;**48**:168–74.
21. Sentongo TA, Semeao EJ, Piccoli DA, et al. Growth, body composition, and nutritional status in children and adolescents with Crohn's disease. *J Pediatr Gastroenterol Nutr* 2000;**31**:33–40.
22. Werkstetter K, Bechtold-Dalla Pozza S, Filipiak-Pittroff B, et al. Long-term development of bone geometry and muscle in pediatric inflammatory bowel disease. *Am J Gastroenterol* 2011;**106**:988–98.
23. Bechtold S, Alberer M, Arenz T, et al. Reduced muscle mass and bone size in pediatric patients with inflammatory bowel disease. *Inflamm Bowel Dis* 2010;**16**:216–25.
24. Burnham J, Shults J, Semeao E, et al. Body-composition alterations consistent with cachexia in children and young adults with Crohn disease. *Am J Clin Nutr* 2005;**82**:413–20.
25. Dubner S, Shults J, Baldassano R, et al. Longitudinal assessment of bone density and structure in an incident cohort of children with Crohn's disease. *Gastroenterology* 2009;**136**:123–30.
26. Sylvester FA, Leopold S, Lincoln M, Hyams JS, Griffiths AM, Lerer T. A two-year longitudinal study of persistent lean tissue deficits in children with Crohn's disease. *Clin Gastroenterol Hepatol* 2009;**7**:452–5.
27. Wiskin AE, Wootton SA, Hunt TM, et al. Body composition in childhood inflammatory bowel disease. *Clin Nutr* 2011;**30**:112–5.
28. Nagano M, Suita S, Yamanouchi T. The validity of bioelectrical impedance phase angle for nutritional assessment in children. *J Pediatr Surg* 2000;**35**:1035–9.
29. Arvidsson D, Slinde F, Hulthén L. Free-living energy expenditure in children using multi-sensor activity monitors. *Clin Nutr* 2009;**28**:305–12.

30. Arvidsson D, Slinde F, Larsson S. Energy cost in children assessed by multisensor activity monitors. *Med Sci Sports Exerc* 2009;**41**:603–11.
31. Habtezion A, Silverberg M, Parkes R, et al. Risk factors for low bone density in Crohn's disease. *Inflamm Bowel Dis* 2002;**8**:87–92.
32. Greene D, Naughton G. Adaptive skeletal responses to mechanical loading during adolescence. *Sports Med* 2006;**36**:723–32.
33. Hind K, Burrows M. Weight-bearing exercise and bone mineral accrual in children and adolescents: a review of controlled trials. *Bone* 2007;**40**:14–27.
34. Maïmoun L, Sultan C. Effects of physical activity on bone remodeling. *Metabolism* 2011;**60**:373–88.
35. Vicente-Rodríguez G. How does exercise affect bone development during growth? *Sports Med* 2006;**36**:561–9.
36. Frost HM, Schönau E. The "muscle-bone unit" in children and adolescents: a 2000 overview. *J Pediatr Endocrinol Metab* 2000;**13**:571–90.
37. Kohrt W, Bloomfield S, Little K, et al. Physical activity and bone health. *Med Sci Sports Exerc* 2004;**36**:1985–96.
38. Robinson RJ, Krzywicki T, Almond L, et al. Effect of a low-impact exercise program on bone mineral density in Crohn's disease: a randomized controlled trial. *Gastroenterology* 1998;**115**:36–41.
39. Etnier JL, Nowell PM, Landers DM, Sibley BA. A meta-regression to examine the relationship between aerobic fitness and cognitive performance. *Brain Res Rev* 2006;**52**:119–30.
40. Packer N, Hoffman-Goetz L, Ward G. Does physical activity affect quality of life, disease symptoms and immune measures in patients with inflammatory bowel disease? A systematic review. *J Sports Med Phys Fitness* 2010;**50**:1–18.
41. Greenley R, Hommel K, Nebel J, et al. A meta-analytic review of the psychosocial adjustment of youth with inflammatory bowel disease. *J Pediatr Psychol* 2010;**35**:857–69.
42. Ischander M, Zladivar F, Eliakim A, et al. Physical activity, growth, and inflammatory mediators in BMI-matched female adolescents. *Med Sci Sports Exerc* 2007;**39**:1131–8.