ORIGINAL PAPER

Reduced physical activity level and cardiorespiratory fitness in children with chronic diseases

Albane B. R. Maggio · Michaël F. Hofer ·
Xavier E. Martin · Laetitia M. Marchand ·
Maurice Beghetti · Nathalie J. Farpour-Lambert

Abstract We aimed to compare physical activity level and cardiorespiratory fitness in children with different chronic diseases, such as type 1 diabetes mellitus (T1DM), obesity (OB) and juvenile idiopathic arthritis (JIA), with healthy controls (HC). We performed a cross-sectional study including 209 children: OB: $n=45$, T1DM: $n=48$, JIA: $n=31$, and HC: $n=85$. Physical activity level was assessed by accelerometer and cardiorespiratory fitness by a treadmill test. ANOVA, linear regressions and Pearson correlations were used. Children with chronic diseases had reduced total daily physical activity counts (T1DM 497±54 cpm, $p=0.003$; JIA 518±28, $p<0.001$, OB 590±25, $p=0.003$) and cardiorespiratory fitness (JIA 39.3±1.7, $p=0.001$, OB 41.7±1.2, $p=0.020$) compared to HC (668±35 cpm; 45.3±0.9 ml kg^{-1}min^{-1}, respectively). Only 60.4% of HC, 51.6% of OB, 38.1% of JIA and 38.5% of T1DM children met the recommended daily 60 min of moderate-to-vigorous physical activity. Low cardiorespiratory fitness was associated with female gender and low daily PA. Conclusion: Children with chronic diseases had reduced physical activity and cardiorespiratory fitness. As the benefits of PA on health have been well demonstrated during growth, it should be encouraged in those children to prevent a reduction of cardiorespiratory fitness and the development of comorbidities.

Keywords Cardiorespiratory fitness · Juvenile idiopathic arthritis · Obesity · Physical activity · Type 1 diabetes mellitus · Children

Introduction

There is increasing evidence that regular physical activity (PA) during childhood reduces multiple health risk factors. At least 60 min per day of moderate-to-vigorous physical activity (MVPA) are generally recommended in school-age children to improve body composition, cardiovascular risk factors, cardiorespiratory fitness (CRF), bone mineral density and well-being [32]. Although several studies investigated PA and CRF in children with different chronic diseases, such as obesity, type 1 diabetes mellitus or juvenile idiopathic arthritis [7, 34, 36], no study have evaluated if these children meet the current recommendation.

The prevalence of childhood overweight is increasing rapidly worldwide, reaching 30% of children in some industrialized countries [23] and resulting in increased risk of chronic diseases, such as cardiovascular diseases [31]. The benefits of PA in the prevention and treatment of cardiovascular diseases have indeed been well-demonstrated in adults [12]. However, overweight and obese children are known to be less active and have a lower CRF than healthy subjects [7, 35]. Nowdays, the treatment of childhood obesity usually includes exercise, dietary and behavioural interventions.

A. B. R. Maggio (✉) · X. E. Martin · L. M. Marchand ·
M. Beghetti · N. J. Farpour-Lambert
Paediatric Cardiology Unit, Department of Child and Adolescent,
University Hospitals of Geneva,
6, rue Willy-Donzé,
1211 Geneva 14, Switzerland
e-mail: albane.maggio@hcuge.ch

M. F. Hofer
Multisite Centre for Paediatric Rheumatology,
University Hospitals of Geneva,
1211 Geneva, Switzerland

M. F. Hofer
Multisite Centre for Paediatric Rheumatology,
University Hospitals of Lausanne,
1011 Lausanne, Switzerland

Type 1 diabetes mellitus (T1DM) affects one in 500 children and is associated with multiple health risk factors, such as hypertension or dyslipidemia [1, 17]. Exercise is highly recommended in T1DM patients for its benefits on various aspects including cardiovascular diseases risk factors [8] and CRF [14, 21]. However, T1DM patients often reduce their level of PA [36].

Juvenile idiopathic arthritis (JIA) is the most common rheumatic disease during childhood and is a leading cause of disability. The estimated annual incidence of JIA is between seven and 21 new cases per 100,000 children per year in European countries [24]. Children with this condition are often less physically active than their peers [13, 34]. However, several studies seem to show that there is no correlation between physical fitness and the severity of the disease [11, 27], though some studies have shown an improvement of disease' signs and symptoms or CRF after exercise training [16, 30]. This led to the inclusion of physical conditioning in treatment protocols [16]. However, few clinicians prescribe exercise to their patients or few children perform activities due to fear of pain or worsening of the disease.

In order to improve exercise prescription in patients with chronic diseases, it is important to quantify their PA level and exercise tolerance. Therefore, the primary purpose of this study was to compare the PA level and cardiorespiratory fitness in children and adolescents with different chronic conditions, such as obesity, T1DM and JIA, with healthy subjects. We also aimed to determine whether their physical activity level met the current guidelines for health, and we search for factors associated with cardiorespiratory fitness.

Materials and methods

This was a cross-sectional study including 209 children and adolescents aged 4.8 to 17.9 years: 45 were obese, 48 had T1DM, 31 had JIA and 85 were healthy. Obese children were younger than the other (Table 1). Patients were recruited from the Department of Child and Adolescent of the University Hospitals of Geneva and Lausanne.

Obesity was defined as age- and gender-specific BMI above the 97th percentile, based on the German references [19]. Forty-five of 55 eligible patients accepted to participate in the study.

All patients (47 patients) with T1DM (WHO criteria) were identified from the diabetes clinic registry and eligible subjects (27 patients) were recruited in the study (mean disease duration of 3.3±0.3 years).

Patients with JIA (criteria of the International League Association of Rheumatology), followed at the Multisite

Centre for Paediatric Rheumatology, were invited to take part in this study (mean disease duration of 2.6± 0.5 years). They were included in the study if they did not have any cardiac, pulmonary or renal complications. Only two children out of 33 refused to be tested. Twelve (38.7%) had oligoarticular, eight (25.8%) polyarticular, nine (29.0%) enthesitis-related arthritis and two (6.5%) systemic JIA. Twenty three of 30 (76.7%) (one missing value) had active disease with seven active and three limited joints on average. Mean pain visual analogue scale (VAS) before testing was of one out of 10 [min–max: 0–6.2].

Exclusion criteria for all patients were (1) the presence of another chronic disease; (2) any medications (except insulin for T1DM or glucocorticoids/disease modifying anti-rheumatic drugs for JIA), which might influence cardiovascular function, body composition or metabolism taken in the preceding 6 months; (3) hospitalization in the preceding year; or (4) family history of dyslipidemia or systemic hypertension.

Healthy children were recruited from peers of the diseased subjects and in local schools. Subjects were asked to participate in the study if they met each of the following eligibility criteria: (1) good health and no recent (past 2 years) systemic illness or hospitalization lasting more than 3 weeks; (2) no known history of chronic disease; (3) no medications or hormones, which might influence cardiovascular function, body composition, lipid or glucose metabolism in the preceding 6 months.

Procedures

Participants visited the Children's Hospital and underwent identical testing. Observers were blinded to subject grouping, except for obese children.

Anthropometry

We assessed body weight to the nearest 0.1 kg using an electronic scale (Seca™, Germany), height to the nearest 0.1 cm using a Harpenden stadiometer and BMI was calculated as height/weight squared (kg m^{-2}).

Cardiorespiratory fitness

Cardiorespiratory fitness was assessed as peak oxygen consumption (VO$_2$ peak) measured by direct gas analysis (Vmax Spectra™, Vyasis Healthcare GE, USA) during a treadmill test (Marquette 2000™ GE, USA). We used a valid protocol [4]. Subject walked or ran on the treadmill at a constant speed which varied by age and physical

Table 1 Anthropometric measurements per group

N	T1DM 48	JIA 31	OB 45	HC 85
Age (years)	10.7±0.4 (e)	10.8±0.5 (f)	9.1±0.3 (e, f)	10.1±0.3
Weight (kg)	40.0±2.2 (e)	36.2±2.2 (f)	49.6±2.6 (c, e, f)	35.5±1.4 (c)
Height (cm)	143.9±2.5	141.3±3.2	138.7±1.6	141.7±1.7
BMI (kg cm^{-2})	18.6±0.4 (e)	17.6±0.5 (f)	25.2±0.8 (c, e, f)	17.0±0.3 (c)
Past year PA (h week^{-1})	3.9±0.6 (e)	4.6±0.6 (f)	0.9±0.2 (c, e, f)	5.3±0.6 (c)

T1DM type 1 diabetes mellitus, *JIA* juvenile idiopathic arthritis, *OB* obese, *HC* healthy children

Mean and standard deviation

$p < 0.05$ between groups: (a) HC and T1DM, (b) HC and JIA, (c) HC and OB, (d) T1DM and JIA, (e) T1DM and OB, (f) JIA and OB

Adjusted for age

capacity (6.0–9.6 km h^{-1}). The speed was chosen according to the spontaneous running speed of the child and the heart rate at the beginning of the test, which had to be below 140 beats/min. The grade of the treadmill increased by 2.5% every 2 min until the subject was exhausted. Maximal cardiac rhythm, respiratory quotient and VO$_2$ peak were recorded at the end of the test. Tests were considered valid if the child showed clinical signs of exhaustion and one or more of the following criteria were reached: (1) heart rate above 195 beats/min and (2) respiratory quotient above 1.0.

Physical activity

Objective measures of PA level were obtained using a uniaxial accelerometer (Actigraph™ MT 6471, MTI, Florida, USA). The monitor was attached above the iliac crest of the right hip and was worn all day long for 7 days, except during bathing or swimming. The Excel™ software was used for data reduction and further analysis. Only periods between 8 a.m. and 9 p.m. were analyzed. For this study, "zero activity" periods of 20 min or longer were interpreted as being due to unworn accelerometers and were removed from the total activity count. Data was expressed as mean activity counts per registered time (cpm). We used cut-offs of different intensity levels, where sedentary behaviour was defined as less than 500 cpm and moderate-to-vigorous physical activity (MVPA) as more than 2,000 cpm [9]. Children who did not manage to record more than 600 min d^{-1} of activity for at least 4 days, including at least 2 week days and 1 weekend day (mean of 6.3± 1.1 days), were excluded from further analysis. In our groups, 13 of 48 T1DM, 22 of 31 JIA, 31 of 45 obese and 54 of 85 healthy children fulfilled the above criteria. The majority of excluded data came from defective monitors; a small proportion (six out of 89) was monitors worn less

than 4 days. There was no difference in term of age, weight, height, BMI and body composition between children who wore and do not wore the monitor. We used the US Department of Health and Human Services guideline for the recommendation of 60 min of MVPA per day [29].

Statistical analysis

Statistical analyses were performed using the SPSS software 15.0 (Chicago, IL, USA). All data screened for normality using Kolmogonov–Smirnov test, and we successfully transformed disease duration (log) and past year physical activity (log). Data are presented as mean and standard deviation. Statistical differences between groups were analyzed using ANOVA and Chi-square or Fisher test with Bonferroni post hoc test. We used ANCOVA for age-dependant variables, such as PA level and VO$_2$ peak. To analyze the associations between PA, CRF and other variables, we performed univariate linear regressions analysis, Pearson correlations or partial correlations to control for age. p value was considered as significant if below 0.05.

The Mother and Child Ethics Committee of the University Hospitals of Geneva approved this study and informed written consent was obtained from both parent and child.

Results

Physical characteristics of subjects are presented in Table 1. The proportion of female and male was similar among groups.

Physical activity

We compared the PA level among groups with chronic condition and healthy subjects (Fig. 1). The total amount of
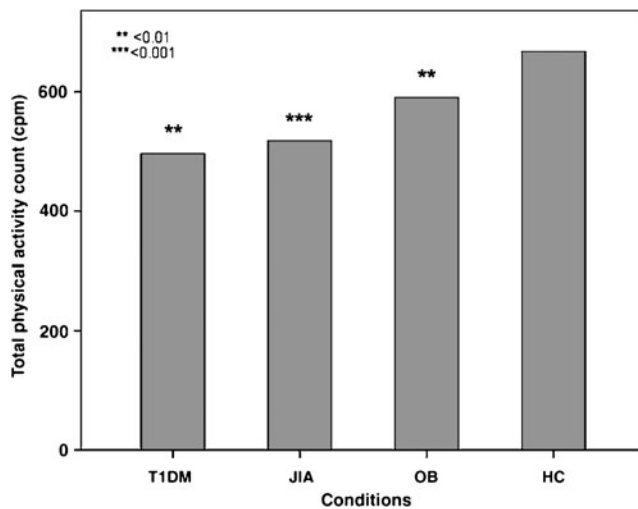
Fig. 1 Physical activity level comparison per groups. *cpm* count per minute, *T1DM* type 1 diabetes mellitus, *JIA* juvenile idiopathic arthritis, *OB* obese, *HC* healthy children. *Graph* represents mean. Age-adjusted statistical difference between disease groups and healthy group is represented with *asterisks*

PA was inversely related to age in both diseased and healthy groups (healthy: $t=-2.6$, $p=0.013$; diseased children: $t=-3.8$, $p=0.001$). After adjusting for age, total daily PA was different among the four groups ($F=7.2$, $p<0.001$), being lower in T1DM (497 ± 54 cpm, $F=6.19$, $p=0.003$), JIA (518 ± 28, $F=9.47$, $p<.001$) and obese (590 ± 25, $F=6.33$, $p=0.003$) compared to healthy children (668 ± 35). Among diseases, JIA patients had lower PA than obese subjects ($F=7.35$, $p=0.002$). In JIA patients, PA was not associated with type or activity of the disease ($p=0.092$), articular pain ($p=0.168$), number of articulation involved ($p=0.138$) or limited ($p=0.566$). There were no correlations between PA and disease duration either in JIA ($p=0.348$) or in T1DM ($p=0.882$) children.

When adjusted for age (adjusted R^2: 13.6%), male gender ($R=0.671$, $p=0.001$), weight ($R=0.460$, $p=0.036$) and height ($R=0.610$, $p=0.003$) were positively correlated to PA level in JIA children. In HC children, only VO$_2$ peak ($R=0.321$, $p=0.019$) and no variable in obese children was correlated to PA level.

The time spent in sedentary PA (T1DM 77%; JIA 73.8%; obese 70.9%; healthy 69.7%, $p<0.01$) was different between every group when adjusted for age. Significant differences in time spent in MVPA were found only between healthy children (9.1% of time spent in MVPA) and JIA (6.9%, $p=0.036$). However, obese (7.7% of time spent in MVPA) and T1DM (6.9%) children tend to spent less time in MVPA than healthy subjects ($p=0.070$ and $p=0.079$, respectively). Figure 2 presents the percentage of children meeting the international recommendations of 60 min of MVPA per day. The mean time spent in MVPA was of 54.0 ± 6.5 min for T1DM, $54.1\pm$
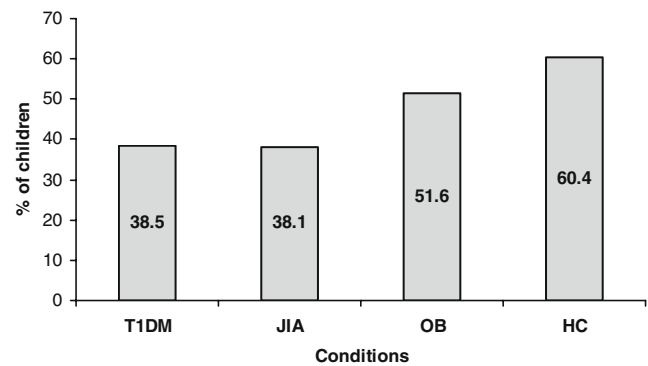

Fig. 2 Percentage of children meeting the international recommendation of 60 min of MVPA per day. *MVPA* moderate to vigorous physical activity, *T1DM* type 1 diabetes mellitus, *JIA* juvenile idiopathic arthritis, *OB* obese, *HC* healthy children

5.7 for JIA, 60.0 ± 3.2 for OB and 71.3 ± 4.5 for HC children.

When groups with chronic diseases were combined, their total amount of PA was 18.1% [95% CI: 43.1–197.4] lower compared to the healthy group ($p=0.004$).

Cardiorespiratory fitness

Cardiorespiratory fitness adjusted for age was higher in healthy children compared to JIA and OB ($p<0.05$) (Fig. 3). All groups had similar maximal heart rate (T1DM, 195 ± 6.9; JIA, 190.6 ± 13.4; OB, 193.5 ± 8.3 and HC, 193.7 ± 8.9 beats/min; $p>0.05$ for all); however, JIA had lower peak respiratory quotient than every other group (T1DM, 1.04 ± 0.08; OB, 1.08 ± 0.05; HC, 1.04 ± 0.1 vs. JIA, 0.96 ± 0.11; $p<0.05$). When groups with chronic conditions
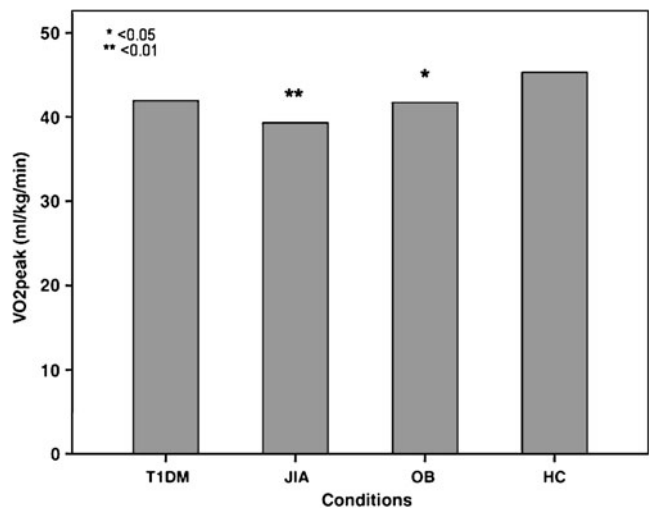

Fig. 3 Cardiorespiratory fitness comparison between groups. *VO$_2$ peak* peak oxygen consumption, *T1DM* type 1 diabetes mellitus, *JIA* juvenile idiopathic arthritis, *OB* obese, *HC* healthy children. *Graph* represents mean. Age-adjusted statistical difference between disease groups and healthy group is represented with *asterisks*

were combined, they had 9% [95% CI: 1.60–6.45] lower CRF than healthy controls ($p=0.001$).

Cardiorespiratory fitness was inversely correlated with disease activity and articular limitation in JIA patients ($p=0.006$ and $p=0.013$, respectively), but was not related to disease duration either in JIA ($p=0.346$) or in T1DM ($p=0.482$) patients. We observed that male gender and high daily MVPA were associated with high VO_2 peak (Table 2). But there was no correlation between sedentary time and VO_2 peak in children with chronic diseases. We found only an inverse relationship between VO_2 peak and sedentary-to-light PA when including all children ($p=0.024$). When all children are taken together, those meeting the recommended 60 min per day of MVPA, had higher VO_2 peak (44.9 ± 8.7 vs. 40.8 ± 9.3 ml/kg/min; $p=0.015$). However, when we looked separately at the different groups, there are no differences ($p>0.05$ for all groups).

Discussion

Physical activity (PA) is a main determinant of health in children and this is of particular importance in young patients with chronic diseases to prevent the development of co-morbidities such as cardiovascular diseases [32]. In our study, we show that children with different chronic conditions (obesity, T1DM and JIA) have reduced total daily PA and lower cardiorespiratory fitness (CRF) compared to healthy subjects. The majority of our patients with chronic diseases do not meet the recommended 60 min of MVPA per day, with only 38% of JIA and T1DM reaching this amount compared to 60% of healthy children. Children with T1DM and JIA should increase their MVPA by only 6 min per day to achieve the recommendations.

Our findings emphasize the need to encourage PA and reduce sedentary behaviours in children with chronic

Table 2 Pearson correlation for VO_2 peak (in ml kg^{-1} min−1)

Variables	Pearson correlation	
	R	p value
Age	0.009	0.901
Gender	0.206	0.003*
Height	0.071	0.309
Count per minute	0.221	0.015*
Minutes in MVPA	0.252	0.006*
Past year PA	0.063	0.428
Disease duration	0.058	0.617

VO2 peak peak oxygen consumption, *MVPA* moderate to vigorous physical activity, *PA* physical activity

*$p<0.05$

diseases. However, the optimal dose of PA for health remains to be determined in these patients. They may need more than this amount of time to show positive effects on health; however, no study has looked at this issue. We may assume that PA could prevent the development of cardiovascular complications especially in obese and T1DM subjects [8, 12, 28] and may improve bone mineralization in T1DM and JIA children [10, 26].

In patients with T1DM, our findings confirm, through an objective measurement instead of questionnaire, the observations made in the past [36]. Decreased PA level may be explained by the fear of hypoglycaemic events, the need of frequent capillary glucose measures or difficulties in adjusting insulin doses and carbohydrate intake [3]. We did not find lower CRF in diabetic children; however, some studies did in T1DM adolescents [2, 18]. There was no correlation between PA level and CRF in this population; however, we must recognize that the proportion of valid PA data set was small in this group. Further investigations should be performed in a larger cohort. This problem raises concerns about the feasibility of working with these accelerometers in a clinical setting.

Children with JIA are known to be less active [13, 34] due to pain, fatigue and articular stiffness, producing a vicious cycle of inactivity and deconditioning with reduced CRF [6, 22, 33, 37]. In our study, we confirmed reduced PA level and CRF, with PA being even lower than in obese patients. Cardiorespiratory fitness was particularly reduced in JIA children with active disease and articular limitations, in accordance to previous publications [22, 34], whereas PA level was not related to articular limitations. We may explain this low CRF by a probable physical limitation as they had relatively low respiratory quotient, suggesting a difficulty to complete maximal exercise testing. As juvenile idiopathic arthritis is characterized by acute and remission phases and the timing of testing may explain discrepancies among studies [11, 27].

Childhood obesity is not always seen by paediatricians as a chronic disease, despite statement of the World Health Organisation. Our results confirm that obese children are less active and have lower CRF compared to non-obese subjects [7, 35]. Sedentary behaviours observed in obese children may be due to exercise intolerance, social exclusion, low self-esteem or obesity associated orthopaedic conditions. However, the inverse may also be true, as sedentary behaviour could lead to weight gain and obesity development [25]. Low exercise capacity may be caused by an early exertional dyspnea, as they are known to have a higher energy expenditure during PA compared to normal weight children [20].

We found associations between PA level and CRF only when including all children, these findings being not significant in chronic diseases or healthy groups separately.

Indeed, this relationship remains unclear in healthy children [7, 15, 32] because the levels of PA are not sufficient to expect an increase in VO$_2$ peak. However, it has been shown that subjects with JIA and low CRF are more prone to improve their fitness with regular exercise [5].

In conclusion, the impact of childhood chronic diseases on physical activity level and cardiorespiratory fitness should not be underestimated. As physical activity may prevent the development of co-morbidities, paediatricians and primary care providers should encourage children with chronic diseases to be physically active at least 60 min per day. However, activities should be adapted to the child's capacity and fear. Current guidelines for T1DM patients indicate that all types of activities can be encouraged, except scuba diving and rock climbing. In JIA children, contact sports and high impact activities should be avoided, especially during acute phases. Finally, obese children should be encouraged to practice various types of moderate intensity activities including strength training. Further research is however needed to determine which volume and intensity of exercise is beneficial to reduce health risk factors in different chronic conditions.

References

1. The DCCT Research Group (1992) Lipid and lipoprotein levels in patients with IDDM diabetes control and complication. Trial experience. Diab Care 15:886–894
2. Austin A, Warty V, Janosky J et al (1993) The relationship of physical fitness to lipid and lipoprotein(a) levels in adolescents with IDDM. Diab Care 16:421–425
3. Bernardini AL, Vanelli M, Chiari G et al (2004) Adherence to physical activity in young people with type 1 diabetes. Acta Biomed 75:153–157
4. Blimkie CJ, Cunningham DA, Nichol PM (1980) Gas transport capacity and echocardiographically determined cardiac size in children. J Appl Physiol 49:994–999
5. Brage S, Wedderkopp N, Ekelund U et al (2004) Features of the metabolic syndrome are associated with objectively measured physical activity and fitness in Danish children: the European Youth Heart Study (EYHS). Diab Care 27:2141–2148
6. Brewer EJ, Giannini EH, Person DA (1982) Major problems in clinical pediatrics: juvenile rheumatoid arthritis, vol 4, 2nd edn. WB Saunders Company, Philadelphia, PA
7. Butte NF, Puyau MR, Adolph AL et al (2007) Physical activity in nonoverweight and overweight Hispanic children and adolescents. Med Sci Sports Exerc 39:1257–1266
8. Church TS, Cheng YJ, Earnest CP et al (2004) Exercise capacity and body composition as predictors of mortality among men with diabetes. Diab Care 27:83–88
9. Ekelund U, Sardinha LB, Anderssen SA et al (2004) Associations between objectively assessed physical activity and indicators of body fatness in 9- to 10-y-old European children: a population-based study from 4 distinct regions in Europe (the European Youth Heart Study). Am J Clin Nutr 80:584–590
10. Gannotti ME, Nahorniak M, Gorton GE 3rd et al (2007) Can exercise influence low bone mineral density in children with juvenile rheumatoid arthritis? Pediatr Phys Ther 19:128–139
11. Giannini MJ, Protas EJ (1991) Aerobic capacity in juvenile rheumatoid arthritis patients and healthy children. Arthritis Care Res 4:131–135
12. Hagberg JM, Park JJ, Brown MD (2000) The role of exercise training in the treatment of hypertension: an update. Sports Med 30:193–206
13. Henderson CJ, Lovell DJ, Specker BL et al (1995) Physical activity in children with juvenile rheumatoid arthritis: quantification and evaluation. Arthritis Care Res 8:114–119
14. Huttunen NP, Lankela SL, Knip M et al (1989) Effect of once-a-week training program on physical fitness and metabolic control in children with IDDM. Diab Care 12:737–740
15. Katzmarzyk PT, Malina RM, Song TM et al (1998) Physical activity and health-related fitness in youth: a multivariate analysis. Med Sci Sports Exerc 30:709–714
16. Klepper SE, Giannini MJ (1994) Physical conditioning in children with arthritis: assessment and guidelines for exercise prescription. Arthritis Care Res 7:226–236
17. Koivisto VA, Stevens LK, Mattock M et al (1996) Cardiovascular disease and its risk factors in IDDM in Europe. EURODIAB IDDM Complications Study Group. Diab Care 19:689–697
18. Komatsu WR, Gabbay MA, Castro ML et al (2005) Aerobic exercise capacity in normal adolescents and those with type 1 diabetes mellitus. Pediatr Diab 6:145–149
19. Kromeyer-Hauschild KWM, Kunze D et al (2001) Perzentile für den Body-mass-Index für das Kindesund Jugendalter unter Heranziehung verschiedener deutscher Stichproben. Monatsschr Kinderheilk 149:807–818
20. Lazzer S, Boirie Y, Bitar A et al (2003) Assessment of energy expenditure associated with physical activities in free-living obese and nonobese adolescents. Am J Clin Nutr 78:471–479
21. Lehmann R, Kaplan V, Bingisser R et al (1997) Impact of physical activity on cardiovascular risk factors in IDDM. Diab Care 20:1603–1611
22. Lelieveld OT, van Brussel M, Takken T et al (2007) Aerobic and anaerobic exercise capacity in adolescents with juvenile idiopathic arthritis. Arthritis Rheum 57:898–904
23. Lissau I (2004) Overweight and obesity epidemic among children. Answer from European countries. Int J Obes Relat Metab Disord 28(Suppl 3):S10–S15
24. Lovell DJ (2008) Juvenile idiopathic arthritis (13th ed). Primer on the rheumatic diseases. Springer, New York
25. Maffeis C (2000) Aetiology of overweight and obesity in children and adolescents. Eur J Pediatr 159(Suppl 1):S35–S44
26. Maggio ABR FS, Kraenzlin M, Marchand LM, Schwitzgebel V, Beghetti M, Rizzoli R, Farpour-Lambert NJ (2010) Decreased bone turnover in children and adolescents with well controlled type 1 diabetes. J Pediatr Endocrinol Metab 23 (in press)
27. Malleson PN, Bennett SM, MacKinnon M et al (1996) Physical fitness and its relationship to other indices of health status in children with chronic arthritis. J Rheumatol 23:1059–1065
28. Myers J, Prakash M, Froelicher V et al (2002) Exercise capacity and mortality among men referred for exercise testing. N Engl J Med 346:793–801

29. Services DoHaH (2005) "Dietary Guidelines for Americans, 2005." from http://www.health.gov/dietaryguidelines/dga2005/document/.

30. Singh-Grewal D, Wright V, Bar-Or O et al (2006) Pilot study of fitness training and exercise testing in polyarticular childhood arthritis. Arthritis Rheum 55:364–372

31. Steinberger J, Daniels SR (2003) Obesity, insulin resistance, diabetes, and cardiovascular risk in children: an American Heart Association scientific statement from the Atherosclerosis, Hypertension, and Obesity in the Young Committee (Council on Cardiovascular Disease in the Young) and the Diabetes Committee (Council on Nutrition, Physical Activity, and Metabolism). Circulation 107:1448–1453

32. Strong WB, Malina RM, Blimkie CJ et al (2005) Evidence based physical activity for school-age youth. J Pediatr 146:732–737

33. Takken T, Hemel A, van der Net J et al (2002) Aerobic fitness in children with juvenile idiopathic arthritis: a systematic review. J Rheumatol 29:2643–2647

34. Takken T, van der Net J, Kuis W et al (2003) Physical activity and health related physical fitness in children with juvenile idiopathic arthritis. Ann Rheum Dis 62:885–889

35. Trost SG, Kerr LM, Ward DS et al (2001) Physical activity and determinants of physical activity in obese and non-obese children. Int J Obes Relat Metab Disord 25:822–829

36. Valerio G, Spagnuolo MI, Lombardi F et al (2007) Physical activity and sports participation in children and adolescents with type 1 diabetes mellitus. Nutr Metab Cardiovasc Dis 17:376–382

37. van Brussel M, Lelieveld OT, van der Net J et al (2007) Aerobic and anaerobic exercise capacity in children with juvenile idiopathic arthritis. Arthritis Rheum 57:891–897