International Journal of Obesity (2000) 24, 299–305

0307–0565/00 $15.00
www.nature.com/ijo

No effect of gender on different components of daily energy expenditure in free living prepubertal children

A Grund[1], H Vollbrecht[1], W Frandsen, H Krause[2], M Siewers[2], H Rieckert[2] and MJ Müller[1]*

[1]*Institut für Humanernährung und Lebensmittelkunde (Abteilung Ernährung des Menschen) der Christian-Albrechts Universität zu Kiel, Kiel, Germany; and* [2]*Institut für Sport und Sportwissenschaften (Abteilung Sportmedizin) der Christian-Albrechts Universität zu Kiel, Germany*

BACKGROUND: There are limited and controversial data on the influence of gender on metabolic rate in prepubertal children.
OBJECTIVE: To assess the effect of gender on resting energy expenditure (REE), activity-related energy expenditure (AEE), total energy expenditure (TEE) and physical activity level (PAL) in free-living prepubertal children.
DESIGN: Cross-sectional study.
SUBJECTS: 40 prepubertal children (24 boys, 16 girls, 4–11 y old (mean age: 7.0 ± 1.2 y), BMI 13.1–32.0 kg/m^2).
MEASUREMENTS: Energy expenditure was measured by the combination of indirect calorimetry and individually calibrated 24 h heart rate monitoring. Body composition was assessed by anthropometrics and bioelectrical impedance analysis. Socio-cultural and socio-economic factors, as well as activities of daily living, were estimated by questionnaire for the parents. Boys and girls were matched for fat-free mass (FFM, boys: 25.9 ± 8.5 kg; and girls: 24.4 ± 4.5 kg, n.s.) and fat mass (FM, boys: 11.6 ± 5.9 kg; and girls: 10.8 ± 3.3 kg, n.s.).
RESULTS: We found no sex difference in REE, AEE and TEE. PAL was 1.4 ± 0.3 for boys and 1.2 ± 0.4 for girls. REE and TEE were significantly related to FFM ($r = 0.62$, $r = 0.81$, $r = 0.60$). FFM was found to be the most significant determinant of REE ($r^2 = 0.70$). REE accounted for the largest part of the variance in TEE ($r^2 = 0.46$). Gender had no significant effect.
CONCLUSIONS: There is no effect of gender on energy expenditure in prepubertal children.
International Journal of Obesity (2000) **24,** 299–305

Introduction

In adults, males have higher metabolic rates than females.[1] Sex differences have been mainly explained by individual differences in fat-free mass (FFM), which is the major determinant of resting energy expenditure (REE). However, in a respiratory chamber 24 h energy expenditure (total energy expenditure, TEE) and REE were higher in males compared with females after adjusting for differences in body composition, age and activity.[1] These data provided evidence for an influence of gender on energy expenditure independent of sex-differences in FFM.

Contrary to adults, little is known about the possible effect of gender on energy expenditure in prepubertal children. This would be of considerable interest since most of the gender-specific differences in body composition or fat distribution are considered to become manifest after puberty. Energy requirements and dietary recommendations for energy intake are higher for prepubertal boys than girls.[2] However, some authors found no differences in REE and TEE between boys and girls.[3,4] This was contrary to other data. In one study 8–9 y old boys and girls were matched for FFM, and activity-related energy expenditure (AEE) was found to be increased in boys.[5] Gender was also shown to have a significant effect on REE in a group of prepubertal boys, who showed no differences in their mean FFM-values when compared with age-matched girls.[6] In addition, differences in REE and TEE were reported between prepubertal boys and girls with non-significant differences in FFM.[7,8] in 1996, Black *et al* published a database on TEE measurements by doubly labelled water.[9] With respect to 7–13 y old children, TEE was again found to be increased in boys when compared with girls.[9] By contrast, studying prepubertal children Goran *et al* found no effect of gender on TEE, whereas there was a significant influence on REE.[10] This is again contrary to other studies where TEE was increased in boys,[11] but no effect of gender was seen on REE.[12,13] These data suggest an increased AEE in boys. In accordance with these findings the most evident biological correlate of physical activity behaviour

*Correspondence: MJ Müller, Institut für; Humanernährung und Lebensmittelkunde, Agrar-und Ernährungswissenschaftliche Fakultät, Christian-Albrechts-Universität zu Kiel, Düsternbrokker Weg 17-19, 24105 Kiel, Germany.
E-mail: mmueller@nutrfoodsc.uni-kiel.de
Received 22 February 1999; revised 25 May 1999; accepted 7 October 1999

was found to be gender: boys were nearly twice as active as girls in moderate to vigorous physical activities.[13]

Taken together the current data do not provide a clear-cut picture. We therefore reassessed the influence of sex on different components of daily energy expenditure in prepubertal boys and girls matched for FFM.

Methods

Subjects

Forty prepubertal children (24 boys and 16 girls) were examined between July and November 1998. The biological data of these children are represented in Table 1. The investigations were carried out at the Institute of Human Nutrition and Food Science and the Institute of Sport and Sport Science (Department of Sport Medicine) at the Christan-Albrechts-University of Kiel (CAU). The procedures were explained to all parents and children. Parents were asked, using a questionnaire, about socio-cultural (e.g. nationality) and socio-economic (e.g. school education, income of the parents and money spent on food) factors as well as activities of daily living of their children (e.g. TV-viewing or sport activities); (Table 2). The nutrition habits of the children were examined by a food frequency test, which included the main food-groups. The parents had given their informed written consent. The ethical committee of the CAU approved the study.

Table 1 Characteristics of the study population I

	Boys (n = 24)	*Girls (n = 16)*
Age (y)	7.2 ± 1.4 (4.0 – 10.9)	6.8 ± 0.9 (4.9 – 8.2)
Height (cm)	130.3 ± 11.7 (114.0 – 163.7)	127.7 ± 6.5 (113.0 – 138.5)
Weight (kg)	37.1 ± 13.7 (20.0 – 76.7)	34.4 ± 7.5 (23.5 – 49.5)
BMI (kg/m^2)[a]	21.3 ± 4.2 (13.1 – 32.0)	20.9 ± 3.1 (15.5 – 25.6)
TSF (mm)[b]	22.9 ± 8.8 (8.0 – 39.0)	19.8 ± 7.7 (11.0 – 33.0)
BSF (mm)[c]	19.0 ± 7.9 (5.0 – 39.0)	15.3 ± 7.2 (6.0 – 30.0)
ASF (mm)[d]	25.5 ± 12.0 (3.7 – 44.0)	22.7 ± 10.7 (10.0 – 36)
SIF (mm)[e]	26.6 ± 12.9 (3.3 – 54.0)	22.6 ± 10.7 (7.0 – 31.0)
SSF (mm)[f]	21.0 ± 10.7 (4.0 – 46.0)	18.9 ± 10.1 (7.0 – 31.0)
Σ TSF, BSF, SIF, SSF (mm)[g]	90.1 ± 38.6 (22.0 – 146.0)	76.5 ± 35.7 (36.0 – 124.0)
R(Ω)[h]	688.9 ± 51.9 (572.0 – 807.0)	733.6 ± 148.7 (649.0 – 849.0)
XC(Ω)[i]	67.0 ± 7.0 (55.0 – 81.0)	69.4 ± 13.7 (61.0 – 80.0)
Fat mass (%)[k]	28.9 ± 8.1 (10.5 – 41.6)	30.1 ± 5.3 (20.9 – 40.7)
Fat mass (kg)[k]	11.6 ± 5.9 (2.2 – 27.6)	10.8 ± 3.3 (5.0 – 15.1)
Fat-free mass (%)[k]	71.1 ± 8.0 (59.3 – 79.1)	69.9 ± 5.3 (58.4 – 89.5)
Fat-free mass (kg)[k]	25.9 ± 8.5 (18.5 – 32.8)	24.4 ± 4.5 (16.7 – 51.1)

[a]BMI = body mass index. [b]Triceps skinfold. [c]Biceps skinfold. [d]Abdominal skinfold. [e]Suprailiacal skinfold. [f]Subscapular skinfold. [g]Sum of b, c, e and f. [h]Resistance. [i]Reactance. [k]Measured by bioelectrical impedance and anthropometry, calculated according to Goran *et al*.[16] Mean ± s.d. (range).

Table 2 Characteristics of study population II

	Boys (n = 24)	*Girls (n = 16)*
Nationality of the parents (n.s.)		
Germany	21(87.5%)	14(87.5%)
Other country	3(12.5%)	2(12.5%)
Education of the mother (n.s.)		
Junior high school	6(25.0%)	3(18.8%)
Modern secondary school	5(20.8%)	6(37.5%)
Secondary school	5(20.8%)	6(37.5%)
No answer	8(33.3%)	1(6.3%)
Share of the monthly income spent on food (n.s.)		
> 33%	5(20.8%)	8(50%)
< 33%	6(25.0%)	6(37.5%)
No answer	13(54.2%)	2(12.5%)
Membership in a sports club (n.s.)		
Yes	13(54.2%)	7(43.8%)
No	11(45.8%)	9(56.1%)
Time spent on TV viewing per day (n.s.)		
< 1 h/day	4(16.7%)	2(12.5%)
≥ 1 h/day	17(70.8%)	12(75%)
No answer	3(12.5%)	2(12.5%)

Mean (percentage). n.s. = not significant.

Measurement of the body composition

Body composition was measured by anthropometric methods (body weight, body height, triceps-, biceps-, abdominal-, suprailiacal- and the supscapular skinfolds) and by bioelectrical impedance analysis (BIA; Multi-Frequency-Analyzer 2000-M, Data Input GmbH, Frankfurt/M, Germany). All measurements were performed by one investigator (AG). The standard measurement (50 kHz, 800 mA) was used for BIA. The measurements took place in the morning after an overnight fast of 8–12 h and after voiding.[14] In a previous study[15] we compared BIA-derived fat mass with fat mass as assessed by anthropometric measures in 610 5–7 y old children. In that study BIA data systematically overestimated anthropometrically derived fat mass at low fat mass, whereas the opposite occurred at high fat mass. To overcome this problem a combination of anthropometric and BIA data was used in this study, as proposed recently by Goran *et al*,[16] who used DEXA as reference method. The following formula was used:

$$\begin{aligned} \text{FFM (kg)} = {} & (0.16 \times (\text{height}^2/R)) + 0.67 \times \text{weight} \\ & - (0.11 \times \text{triceps skinfold}) \\ & - (0.16 \times \text{subscapular skinfold}) \\ & + (0.43 \times \text{sex}) + 2.41\,\text{kg} \end{aligned}$$

(height (cm), weight (kg), triceps skinfold (mm), subscapular skin fold (mm), sex is 0 for girls and 1 for boys).

Recalculating our previous data using this formula showed a marked reduction of the systematic error (data not shown). However when compared with anthropometric data, there was still some over/underestimation of fat mass by the use of the combined method at low/high fat mass (data not shown).

Measurement of resting energy expenditure (REE)
Resting energy expenditure was measured in the morning, after the children arrived in an overnight fasting state (8–12 h) to the metabolic ward. Measurements were performed by indirect calorimetry (IC). The measurement was performed continuously for 1 h with a GEM (gas exchange measurement, Europa Scientific, Crewe, UK). The subjects were relaxed and the environment was thermoneutral.[14,17] The results of indirect calorimetry were compared with estimated REE data according to the WHO data[18] (Table 3). Predictors of the estimated REE were age, body weight, body height and gender.[14] Resting heart rate was measured with a heart rate (HR) monitor (Physio-Trend, med-NATIC, Munich, Germany; see below). The correlation between heart rate and oxygen consumption (VO_2) of the entire study population at rest was used to calculate a regression for the data (Figure 1).

Ergospirometry
An individual regression line for HR vs O_2 for each child was established on a bicycle ergometer.[19]

Table 3 Energy expenditure of prepubertal children

	Boys (n = 24)	*Girls (n = 16)*
REE_{IC} (MJ/24 h)[a]	5.2 ± 1 (3.6–7.4)	4.7 ± 0.6 (3.9–6.1)
TEE_{HR} (MJ/24 h)[b]	7.3 ± 2.4 (5.0–14.5)	6.5 ± 1.1 (4.9–8.8)
AEE (MJ/24 h)[c]	1.8 ± 1.6 (−0.1–6.6)	1.4 ± 1.1 (0.1–4.1)
PAL (TEE/REE)[d]	1.4 ± 0.3 (1.0–2.0)	1.2 ± 0.4 (1.1–2.0)
Difference (MJ/24 h): *REE_{WHO}[e]–REE_{IC}[a]	0.4 ± 0.5 (−0.3–1.4)	0.7 ± 0.4 (−0.8–1.5)
Difference (%): REE_{WHO}[e]–REE_{IC}[a]	6.6 ± 7.6 (−6.1–20.0)	12.6 ± 6.9 (−11.1–22.4)
Difference (MJ/24 h): *REE_{Black}[f]–TEE_{HR}[b]	1.5 ± 2.4 (−4.7–5.1)	0.7 ± 1.4 (−1.5–3.1)
Difference (%): TEE_{Black}[f]–TEE_{HR}[b]	15.2 ± 25.5 (−47.5–52.0)	8.1 ± 19.4 (−29.4–38.9)

[a]REE = resting energy expenditure from indirect calorimetry. [b]TEE = total energy expenditure from 24 h heart rate monitoring. [c]AEE = activity-related energy expenditure calculated from the difference between (TEE−5%) (−5% = correction for 'diet-induced thermogenesis') and REE. [d]Physical activity level: ratio of TEE and REE. [e]Estimated resting energy requirements according to 'WHO'. [f]Estimated total energy requirements according to Black *et al*. Mean ± s.d. (range). *$P < 0.001$ estimated values *vs* measured values.

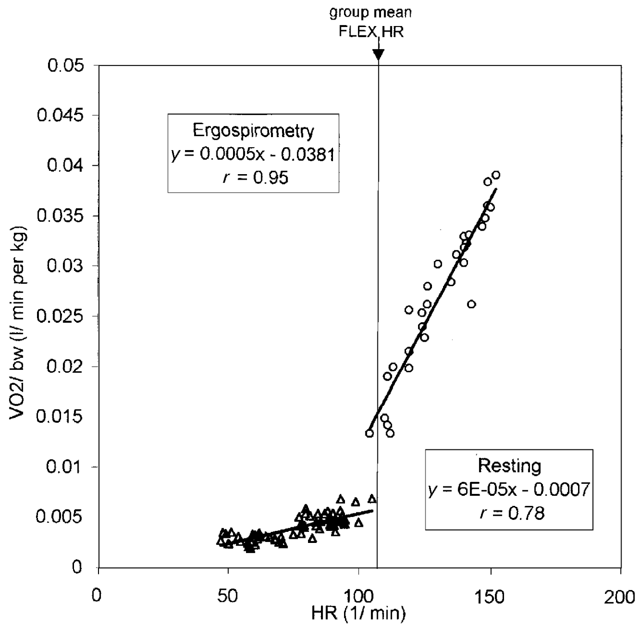

Figure 1 Relationship between oxygen consumpion (VO_2) and heart rate (HR) during rest and ar physical exercise on a bicycle ergometer. Δ relationship between VO2 and HR during rest (Indirect calorimetry); ○ relationship between VO2 and HR during exercise (Ergospirometry); —Mean FLEX HR of the children; bw = body weight.

(Ergostar, PMS Professional Medical Systems, Basel, Switzerland) (Figure 1). The levels of intensity were calculated depending on the weight of the children.[20] The protocol started with an intensity of 0.5 W per kg body weight. The intensity was increased by 0.5 W per kg body weight every 2–3 min.[20] The protocol lasted for 10–12 min. The intensity level was increased when HR and O_2 reached a steady state at the respective intensity level. The highest work load reached in our protocol was 50% of the calculated maximal oxygen consumption.[21] The relationship between HR and O_2 was used to calculate 24 h energy expenditure from 24 h HR monitoring during free living conditions.

Heart rate (= HR) monitoring
The heart rate monitor was fixed with three standard electrodes at the thorax of the children. Measurements were performed continuously (minute-by-minute) during 24 h. In six children (three boys and three girls) the heart rate was measured over 3 days (2 days in the week, 1 day at the weekend) (Table 4). The HR-monitor saved the 24 h HR data. In the present study the FLEX HR was defined as the mean of the highest HR during the sitting measurement at the bicycle ergometer and the lowest HR during light working on the ergometer. Individually FLEX HR was used to discriminate between resting and exercise HR (Figure 1). Total energy expenditure was measured by the FLEX HR-monitoring method.[5,19,22] When HR was below FLEX HR, the regression for O_2 *vs* HR of all probands at rest was used to calculate energy expenditure. For the remain-

Table 4 Intraindividual variation (CV) of the 3 day energy expenditure measurement in six prepubertal children (three boys: mean age, 8.6 ± 2.1 y; mean weight, 35.3 ± 2.9 kg; mean height, 131.7 ± 6.7; three girls: mean age, 8.2 ± 1.9 y; mean weight, 43.8 ± 3.4 kg; mean height, 138.7 ± 12.0 cm)

Subject	*REE (MJ/24 h)*	*Day 1 (during week) TEE (MJ/24 h)*	*Day 2 (during week) TEE (MJ/24 h)*	*Day 3 (during week) TEE (MJ/24 h)*	*CV TEE (%)*
1	5.3	9.3	13.7	14.2	6.7
2	5.1	8.0	5.7	8.6	6.3
3	5.6	7.1	7.0	6.8	0.8
4	5.5	10.8	6.1	9.2	8.5
5	4.3	7.8	6.9	8.2	2.7
6	6.0	7.6	11.9	8.1	7.8
Mean	5.3	8.4	8.6	9.2	5.5
s.d.	0.5	1.2	2.9	2.2	2.6

REE = resting energy expenditure; TEE = total energy expenditure; VC = coefficient of variation.

der of the daytime, when HR was above FLEX HR, energy expenditure was derived from the minute-by-minute recorded HR using the individual child's regression line for the O_2 corresponding to the HR (method 1, TEE_1, according to Schulz *et al*[23]). Alternatively, REE as determined by indirect calorimetry was used for calculation of energy expenditure during periods where HR was below FLEX HR (method 2, TEE_2[22] Figure 2 compares TEE_1 with TEE_2. The activity-related energy expenditure (AEE) was calculated from the difference between TEE minus estimated 'diet-induced thermogenesis' (DIT, assumed to be 5% of TEE), and REE[10] (Table 3). The ratio of TEE and REE was the physical activity level (PAL). With measurement of the 24 h energy expenditure (total energy expenditure, TEE) by HR-monitoring, the 24 h period could be divided into different degrees of physical activity. The results of the measured 24 h energy expenditure by HR-monitoring (TEE_{HR}) were compared with estimated TEE data by doubly labelled water (DLW) obtained as by Black *et al*[9] (Table 2).

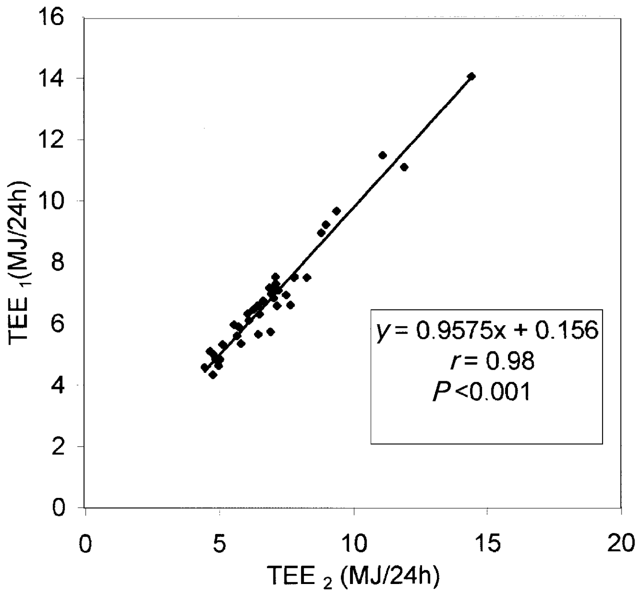

Figure 2 Comparison of two different methods to measure total energy expenditure (TEE). TEE_1: TEE was measured by 24-h heart rate monitoring. For calculation of energy expenditure at HR > FLEX HR the individual regression line between oxygen consumption (VO_2) and HR was used, HR < FLEX HR the group regression line between HR and VO_2 at rest at assessed indirect calorimetry was used. TEE_2: TEE was calculated from HR at moderate to high activities of the whole day. HR > FLEX HR using individual regression between VO" and HR, at HR < FLEX HR resting energy expenditure (REE) was used (compare 22).

Statistical analyses

Excel 97, SPSS for Student Version and Graph Pad Instat were used for the statistical analyses. The significance of the body-data were tested by Student's *t*-test. The chi-square-test was used to test the significance of the questionnaire and food frequency test data. Significance of REE, TEE, AE and PAL data between boys and girls matched for FFM were tested by the unpaired sample *t*-test. Relationships between variables were determined by linear stepwise regression analyses with calculation of Pearson product correlation coefficients. REE, TEE and AEE were the dependent variables. Age, gender, FM and FFM were the independent variables. For total energy expenditure (TEE), resting energy expenditure (REE), sex and age were used as independent variables. Statistical significance is denoted by $P < 0.05$ or $P < 0.001$. All data were presented as mean ± s.d. (range).

Results

Anthropometric and body composition data of the study population are shown in Table 1. No significant differences in mean FFM and FM values were found between boys and girls. There were also no significant differences in socio-cultural and socio-economic factors (Table 2) between girls and boys. There were no significant gender differences in REE, TEE, AEE and PAL (Table 3). Regarding leisure time activities, no significant gender differences were observed (Table 2). However, taken as a whole there was only a weak relationship between the TEE ($r = 0.12$), AEE ($r = 0.15$), PAL ($r = 0.14$) and daily TV-watching questioning the value of a leisure time questionnaire (data not shown). Regarding nutrition, there were no gender differences in the consumption of fruits, vege-

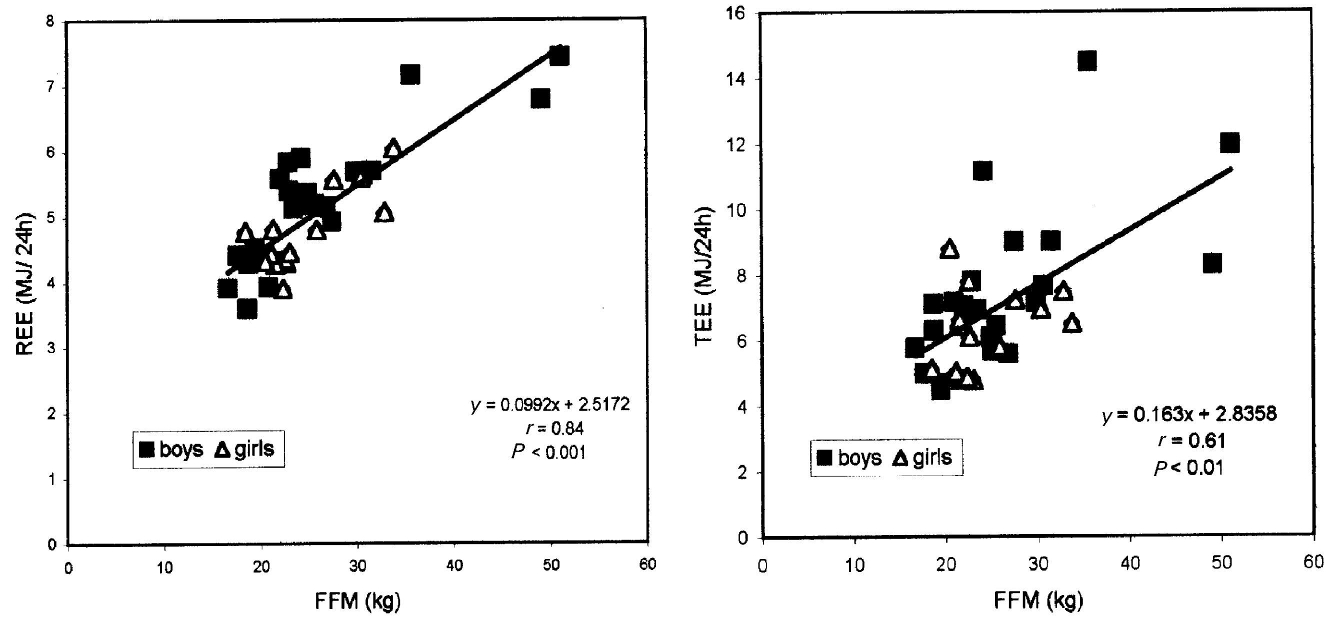

Figure 3 Relationship between fat free mass FFM) at baseline resting energy expenditure (REE) and total energy expenditure (TEE) in 40 prepubertal children. A high fat free mass was associated with a higher REE (r = 0.84, $P < 0.001$) and TEE (r = 0.59, $P < 0.01$).

tables, meat, fat, fast-food, sweets, milk products etc. as assessed by a detailed food frequency questionnaire (data not shown).

Gender had no significant effect on FLEX HR (girls = 114.0 ± 8.4 bpm, boys = 113.2 ± 10.8 bpm). The percentage of times of the day spent at different physical activity levels were also calculated for boys and girls: resting (PAL = 1; girls = 60.8%, boys = 58.4%, n.s.), PAL above 1.5 (girls = 17.4%, boys 18.4%, n.s.), PAL above 1.75 (girls = 16.3%, boys 14.6) and PAL above 2.0 (girls = 14.1%, boys 12.4% n.s. for all activity levels). Measured REE values were lower than the estimated REE data (REE_{WHO}) (Table 3, $P < 0.001$).

The intra-individual variation was tested (subgroup, six children) by 3-day energy expenditure measurement in the six children and was found to be low (Table 4). There was a tendency for higher TEE values during the weekend (Table 3). However, the correlation between TEE assessed on a week-day and TEE measured at the weekend was very strong ($r = 0.95$). Regarding TEE, the significant difference between the estimated TEE_{Black} and measured values (TEE_{HR}) was slightly higher in boys than in girls (Table 3), but the gender difference was not significant (Table 3). With respect to the influence of different calculation procedures, there was a strong correlation between the results of the two different methods to calculate TEE from data obtained by 24 h HR monitoring (TEE_1, TEE_2, see methods for details of the different calculation procedures, $r = 0.98$, $P < 0.001$, Figure 2). Energy expenditure correlated with the fat free mass (REE: $r = 0.81$; TEE: $r = 0.60$, $P < 0.01$, Figure 3).

The results of a stepwise regression analysis showed that fat-free mass explained most of the variance in REE ($r^2 = 0.70$). When body weight was used instead of FFM as an independent variable, body weight ($r^2 = 0.72$) and gender ($r^2 = 0.07$) had a significant influence. REE was the largest factor explaining the variance in TEE ($r^2 = 0.46$). However the power of our analysis was relatively low (power level < 0.7), because of the limited number of children investigated in our study.

Discussion

We showed previously that there are gender specific differences in body composition in prepubertal children.[15] Body weight, fat-free mass, fat mass and waist to hip ratio were significantly increased in 5–7 y old boys when compared to age matched girls.[16] These data were based on measurements performed in 610 prepubertal children. Since (i) FFM is the major determinant of REE and (ii) REE is the major component of TEE, it is thus tempting to speculate that boys had higher values for REE and TEE than girls.

Children's levels of physical activity are highly variable and TEE varied from 4.9 to 14.5 MJ/day (Table 3). We found strong correlations between $FFM_{(x)}$ and $REE_{(y)}$ or $TEE_{(y)}$, respectively (Figure 3). In prepubertal children, FFM was the major determinant of REE (Figure 3) and REE explained most of the variance in TEE (results). In this study boys and girls had similar FFM values. We found no effect of gender on the different components of daily energy expenditure (Table 2). These findings are contrary to data obtained in adults where gender had an independent effect on REE and TEE.[1] Our data are also contrary to some studies on energy expenditure measured in groups of prepubertal boys and girls, who were not matched for FFM.[10,11] However, when prepubertal boys and girls were matched for EFM, most authors found no effect of gender on the different components of daily energy expenditure.[4,7,8]

It is unclear why some authors [5,9–11] came out with different results. Summarizing all available DLW-data, Black found increased TEE-values for prepubertal (i.e. 7–12 y old) boys when compared with girls.[9] Unfortunately, these groups of children were not matched for FFM. In addition children with a broad range of age were studied. Some of the differences between the studies may be explained by the different methods used. Most authors used doubly labelled water (DLW) for the measurement of TEE. In our study a combination of indirect calorimetry and 24 h heart rate monitoring calibrated individually by ergometry was used. Heart rate monitoring has been validated in children and found to show excellent agreement with DLW data at the group level.[5] Thus, it is unlikely that different methodologies explain the different results.

Recently Manios *et al* [24] examined physical activity and physiological fitness parameters in a group of 569 children in Crete. They found that girls watched significantly more TV than boys.[24] In addition boys were more active in unorganized activities, but girls more so in organized activities.[24] The authors proposed that physical activity is not only a physiological parameter. Physical activity and energy expenditure of children may also be affected by influences of seasonality, social environment, ethnicity, geographic location or nutrition.[10,14] In fact the socio-economic status (SES) of the parents has a great influence on physical inactivity, e.g. children with a low SES spent more time watching television.[25–27] In these studies physical inactivity was also associated with childhood obesity, suggesting that inactivity contributes to overweight. However, up to now socio-cultural factors have received little attention with respect to their influence on children's activity patterns. In fact, none of the studies cited took into account the effects of SES or nutrition. In our hands, there were no differences in SES or food consumption between boys and girls.

It is tempting to speculate that differences in geographic location, tradition, school system, family structure, social sate and nutrition habits add to the different results obtained in the different studies. Gender differences in TEE or REE may be detectable under some conditions, e.g. during the winter season, when outdoor activities are reduced, in low income families and in children with low parent support.

Conclusion

Our study population was relatively small, but homogeneous with respect to some determinants of physical activity in children (Table 2). In our hands gender had no effect on the different components of energy expenditure. However there may be differences in other aspects of physical activity, e.g. fitness or muscle strength. Future studies will investigate the possible associations between TEE, REE, body composition data, muscle strength and aerobic fitness in prepubertal boys and girls. Since our children will be followed until puberty, we speculate that, if there are gender differences, they will become apparent at this age.[28] Taken together in prepubertal boys and girls matched for FFM we found no effect or gender on the different components of daily energy expenditure.

Acknowledgements
This work was supported by grants from Verein zur Förderung der Rehabilitationsforschung in Schleswig-Holstein e.V., Lübeck; Wirtschaftliche Vereinigung Zucker, Bonn; Else Kröner-Fresenius Stiftung, Bad Homburg; Bad Schwartau Werke, Bad Schwartau; team success, Selent; and Hansa-Tiefkühlmenü GmbH & Co., Hilter.

References
1 Ferraro R, Lillioja S, Fontvieille AM, Rising R, Bogardus C, Ravussin E. Lower sedentary metabolic rate in women compared with men. *J Clin Invest* 1992; **90**(3): 780–784.
2 Torun B, Davies PS, Livingstone MB, Paolisso M, Sackett R, Spurr GB. Energy requirements and dietary energy recommendations for children and adolescents 1 to 18 years old. *Eur J Clin Nutr* 1996; **50**(Suppl 1): S37–S80.
3 Fontvielle AM, Harper IT, Ferraro RT, Spraul M, Ravussin E. Daily energy expenditure by five-year-old children, measured by doubly labeled water. *J Pediatr* 1993; **123**(2): 200–207.
4 Emons HJG, Groenenboom DC, Westerterp KR, Saris WHM. Comparison of heart rate monitoring combined with indirect calorimetry and the doubly labelled water ($^2H_2{}^{18}O$) method for the measurement of energy expenditure in children. *Eur J Appl Physiol* 1992; **65**: 99–103.
5 Livingstone MBE, Coward WA, Prentice AM, Davies PSW, Strain JJ, McKenna PG, Mahoney CA, White JA, Stewart CM, Kerr MJJ. Daily energy expenditure in free-living children: comparison of heart-rate with doubly labeled water ($^2H_2{}^{18}O$) method. *Am J Clin Nutr* 1992; **56**: 343–352.
6 Maffeis C, Schutz Y, Micciolo R, Zoccante L, Pinelli L. Resting metabolic rate in six- to ten-year-old obese and nonobese children. *J Pediatr* 1993; **122**(4): 556–562.
7 Goran MI, Carpenter WH, Poehlman ET. Total energy expenditure in 4- to 6 yr-old children. *Am Physiol Soc* 1993; **264**: E706–E711.
8 Bitar A, Vermorel M, Fellmann N, Coudert J. Twenty-four-hour energy expenditure and its components in prepubertal children as determined by whole-body indirect calorimetry and compared with young adults. *Am J Clin Nutr* 1995; **62**: 308–315.
9 Black AE. Human energy expenditure in affluent societies: an analysis of 574 doubly-labelled water measurements. *Eur J Clin Nutr* 1996; **50**: 72–92.
10 Goran MI, Nagy TR, Gower BA, Mazariegos M, Solomons N, Hood V, Johnson R. Influence of sex, seasonality, ethnicity, and geographic location on the components of total energy expenditure in young children: implications for energy requirements. *Am J Clin Nutr* 1998; **68**: 675–682.

11 Greene LC, Livingstone MBE, McGloin AF, Webb SE, Jebb SA, Prentice AM. Daily energy expenditure in free-living children: comparison of Caltric motion sensors with the doubly-labelled water method (Abstract). *Procl Nutr Soc* 1994; **53**: 207–221.
12 Trost SG, Pate RR, Sannders R, Ward DS, Felton G. Gender differences in physical activity and determinants of physical activity in rural fifth grade children. *J School Health* 1996; **66**: 145–150.
13 Johnson RK, Russ J, Goran MI. Physical activity related energy expenditure in children by doubly labelled water as compared with the Caltrac accelerometer. *Int J Obes* 1998; **22**: 1046–1052.
14 Müller MJ. *Ernährungsmedizinische Praxis*. Springer: Berlin, 1998.
15 Mast M, Körtzinger I, König E, Müller MJ. Gender differences in fat mass of 5–7 year old children. *Int J Obes* 1998; **22**: 878–884.
16 Goran MI, Driscoll P, Johnson R, Nagy TR, Hunter G. Cross-calibration of body composition techniques against dual-energy x-ray absorptiometry in young children. *Am J Clin Nutr* 1996; **63**: 299–305.
17 Müller MJ, von zur Mühlen A, Lautz HU, Schmidt FW, Daiber M, Hürter P. Energy expenditure in children with type 1 diabetes: evidence for increased thermogenesis. *Br Med J* 1989; **299**: 487–491.
18 World Health Organization. *Energy and protein requirements*. Report of a Joint FAO/WHO/UNU Expert Consultation, 1995.
19 Livingstone MBE. Heart-rate monitoring: the answer for assessing energy expenditure and physical activity in population studies? *Br J Nutr* 1997; **78**: 869–871.
20 Neumann G, Schüler KP. *Sportmedizinische Funktionsdiagnostik*. Ambrosius Borth, 1994.
21 Astrand I. Maximale O_2-Aufnahme in Beziehung zum Körpergewicht bei 4–33 jährigen Menschen weiblichen und männlichen Geschlechts. In Mellerowicz H (ed). *Der Kreislauf des Jugendlichen bei Arbeit und Sport*. Karger: Berlin, 1981, pp 27–29.
22 Spurr GB, Prentice PD, Murgatroyed PR, Goldberg MS, Reina JC, Christman NT. Energy expenditure from minute-by-minute heart rate recording: comparison with ndirect calorimetry. *Am J Clin Nutr* 1988; **48**: 552–559.
23 Schulz S, Westerterp KR, Brück K. Comparison of energy expenditure by the doubly labeled water technique with energy intake, heart rate, and activity recording in man. *Am J Clin Nutr* 1989; **49**: 1146–1154.
24 Manios Y, Kafatos A, Cordington C. Gender differences activity and physical fitness in young children in Crete. *J Sports Med Phys Fitness* 1999; **39**: 24–30.
25 Dietz WH, Gortmaker L. Do we fatten our children at the television set? Obesity and television viewing in children and adolescents *Pediatrics* 1985; **75**(5): 807–811.
26 Jeffery RW, French SA. Epidemic obesity in the United States: are fast food and television viewing contributing? *Am J Public Health* 1998; **88**(2): 277–280.
27 Müller MJ, Körtzinger I, Mast M, König E. Prävention der Adipositas. Deutsches rzteblatt, 1998; **34**/**35**: 1518–1521.
28 Goran MI, Reyholds KD, Lindguist CH. Role of physical activity in the prevention of obesity in children. *Int J Obes* 1999; **23**(Suppl 2): 18–33.