# Cycling peak power in obese and lean 6- to 8-year-old girls and boys

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**Abstract:** The purpose of this study was to investigate the possible effect of the difference in percentage body fat (%BF) and fat-free mass (FFM) on cycling peak power (CPP) in 6- to 8-year-old obese and lean untrained girls and boys. Obese (35 girls, 35 boys) and lean (35 girls, 35 boys) children were measured for obesity, %BF, calculated from skinfold measurements. FFM was calculated as body mass (BM) minus body fat. A force–velocity test on a cycle ergometer was used to measure CPP. CPP was related to anthropometric variables using standard and allometric models. CPP in absolute terms was higher in obese children than in lean children irrespective of gender. BM-related CPP was significantly lower in obese children than in lean ones, whereas no effect of obesity appeared on FFM-related CPP. Velocity at CPP ($V_{opt}$) was significantly lower and force at CPP ($F_{opt}$) was significantly higher in girls than in boys. Muscle power production was unaffected by obesity in children. Low BM-related CPP could explain the difficulty of taking up physical activities that are body-mass related in obese children. Gender difference for $V_{opt}$ and $F_{opt}$ shows that girls and boys may have different maturation patterns affecting CPP.

*Key words:* children, obesity, gender, muscle power, cycling.

**Résumé :** Le but était d'étudier l'effet possible des différences de pourcentage de masse grasse et masse maigre sur le pic de puissance sur bicyclette chez des garçons et filles obèses et non obèses non entraînés de 6 à 8 ans. Des enfants obèses (35 filles, 35 garçons) et non obèses (35 filles, 35 garçons) ont été mesurés. Le pourcentage de masse grasse calculé à partir de la mesure des plis cutanés a été utilisé pour déterminé l'obésité. La masse maigre a été calculée comme correspondant à la différence entre la masse corporelle et la masse grasse. Un test de force–vitesse sur bicyclette ergométrique a été utilisé pour mesurer le pic de puissance. Le pic de puissance a été exprimé en fonction de variables anthropométriques en utilisant des modèles standard et allométrique. Le pic de puissance est plus élevé chez les enfants obèses que chez les non obèses quel que soit le sexe. Exprimé en fonction de la masse corporelle le pic de puissance est significativement plus faible chez les enfants obèses comparés aux non obèses, alors que l'obésité n'a aucun effet sur le pic de puissance exprimé en fonction de la masse maigre. La production du pic de puissance n'est pas affectée par l'obésité chez l'enfant. La faible valeur du pic de puissance exprimée en fonction de la masse corporelle pourrait expliquer les difficultés rencontrées par les enfants obèses à s'engager dans des activités nécessitant le port de la masse corporelle. L'effet du sexe sur $V_{opt}$ et $F_{opt}$ montre que filles et garçons présentant une différence de maturation, la production du pic de puissance est différente.

*Mots-clés :* enfants, obésité, sexe, puissance musculaire, pédalage.

## Introduction

The prevalence of obesity in children is increasing in developed countries and is associated with the early development of pathological symptoms such as cardiovascular diseases or insulin-resistance syndrome (Steinberger and Daniels 2003). Excessive increase in body fat is the consequence of an imbalance between energy intake and energy expenditure; obese children have low levels of physical activity leading to low energy expenditure (Trost et al. 2001). Increase in energy expenditure with physical activity contributes to reduce fat mass in obese children (Epstein et al. 1995). In the majority of games and sports (racket sports, basketball, jumping events, rugby, ice hockey), children are essentially involved in short-term, high-intensity exercise. Bailey et al. (1995) have shown that children engaged spontaneously in very short bursts of intense physical activity (95% lasting less than 15s) interspersed with varying intervals of low and moderate intensity. Thus, an alteration of anaerobic performance may compromise the participation of children in games and sports and modify the spontaneous pattern of physical activity. However, overweight children

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perceive physical activity that involves the use of body mass (BM) as not enjoyable and report low self-efficacy (Pender et al. 2002; Fulkerson et al. 2004). This is a consequence of the high body fat that constitutes a handicap to performance in obese children. In adolescents, fat-free mass (FFM)-related cycling peak power (CPP) is similar in obese and non-obese subjects, showing that muscle contractile properties are not impaired by obesity (Duché et al. 2002). However, these authors also observed that FFM was higher in obese adolescents and was associated with higher CPP when expressed in absolute terms. Bosco et al. (1986) showed in adults that extra load could contribute to the increase in muscle power. Therefore, it is plausible that excess fat mass is a training stimulus in obese persons that increases their muscle power and favours an increase in muscle mass. However, other studies have shown that muscle contractile properties could be altered with obesity. Motor unit activation during knee extensor exercise is reduced in obese 15- to 18-year-old boys (Blimkie et al. 1990). Finally, the lower number of jumps in a lateral jumping test by obese 6- to 9-year-old children compared with lean children indicates that motor abilities, especially temporal coordination, are altered with obesity (Graf et al. 2005).

The force–velocity test on a cycle ergometer allows an accurate measurement of muscle power independent of body mass as the resistive load. Although it is a practical technique, to our knowledge no study has previously examined maximal anaerobic performance assessed by CPP in obese children of both genders and compared it with CPP in their lean peers. Thus, the purpose of this study was to determine CPP and its components, optimal velocity ($V_{opt}$) and optimal force ($F_{opt}$), in untrained children and to identify possible differences between obese and lean girls and boys. Scaling performance variables with allometric techniques (power function) has been shown in several studies as more appropriate than standard ratio to remove the confounding effect of body size in different groups. Thus, we used both traditional standard and allometric ratios to study the influence of anthropometric variables on CPP in children (Nevill et al. 1992).

The high BM carried by obese subjects could be a training stimulus favouring an increase in muscle power (Duché et al. 2002). However, owing to their young age, obese children also have a short history of obesity and the duration of a large BM may be too short to induce an increase in muscle power. Combined with an altered temporal coordination (Graf et al. 2005), this might affect cycling coordination and result in a lower $V_{opt}$; we therefore hypothesize that CPP would be lower in obese than in lean children.

## Materials and methods

Four groups of 35 children (6–8 years old) were formed according to obesity with percentile curves for body fat specific to boys and girls (McCarthy et al. 2006). Children were drawn within a total population of 529 children who volunteered for the study from 15 elementary schools. Children involved in regular sports training or physical activities out of school for more than 3 h/week were excluded. Prior to the study, the experimental design was explained to all of the children and their parents. Both children and parents signed consent forms. The design of the study was approved by an ethical committee of Academic Inspection. This study is a part of a French program for the prevention of obesity (Programme National Nutrition et Santé).

### Experimental design

Children were classified into four groups (male obese (MOB), male lean (MLE), female obese (FOB), female lean (FLE), according to gender and body fat (%BF), based on body fat reference curves for children established by McCarthy et al. (2006): MOB ($n$ = 35) and FOB ($n$ = 35) with %BF higher than 95th percentile, and MLE ($n$ = 35) and FLE ($n$ = 35) with %BF under 85th percentile.

### Protocol

Each child participated in two sessions. The first session was used for anthropometric measurements. Height and body mass (BM) were measured. Bicipital, tricipital, subscapular, and supra-iliac skinfolds measured with a Harpenden skinfolds calliper in triplicate were used to calculate %BF from Brook (1971) equations. Measurements were taken by an experienced anthropometrist. Mast et al. (2002) have shown that CVs for three repeated measurements by an experienced anthropometrist were 4.2%, 6.8%, 5.1%, and 5.3% for bicipital, tricipital, subscapular, and supra-iliac skinfolds in children.

Fat-free mass (FFM) was calculated from BM and %BF as follows: $\text{FFM} = \text{BM} - (\%\text{BF} \times \text{BM}/100)$.

During the second session, a short-term cycling power (force–velocity) test was performed on a calibrated friction-loaded ergometer (Ergomeca, Sorem, Toulon, France) with the following features: 17 cm crank length, 15.6 kg flywheel mass, and 6.12 m/pedal revolution. A photoelectric sensor measured the rolling displacement of the flywheel 4 timesrevolution (or 16 times/pedal revolution). A second sensor detected beginning of the crank gear rotation cycle.

Each subject performed a 2-min warm-up at low intensity with a brief sprint (<8 s) against a low braking force at the end.

The test consisted of two short ‘‘all-out’’ sprints against different braking loads applied in a randomized order: 25 and 50 g·kg body mass$^{-1}$. Three minute rests were allowed between sprints (Doré et al. 2000). When the pedalling velocity reached maximal value (<8 s) sprints were stopped by the experimenters. Children were instructed to stay seated on the saddle during the sprint and to pedal as fast as possible. Toe clips were used to prevent the feet from slipping off the pedals. Each subject benefited from vocal encouragements from the experimenters. Doré et al. (2003) have shown that when children perform two sprints with a braking force similar to our study the test–retest CV is equal to 4.7%.

### *Calculation of CPP*

During the flywheel acceleration, the subject had to produce a total external force with two components: the frictional force (constant) applied on the flywheel with the braking load, and the inertial force needed to accelerate the flywheel (Lakomy 1986). Instantaneous power was calculated as the product of total external force and pedalling rate and was averaged per half-pedal revolution. Only the highest value of CPP with the two braking loads for each

**Table 1.** Age and anthropometric characteristics of obese and normal weight girls and boys.

| | Age (y) | Height (cm) | Body mass (kg) | BMI ($kg \cdot m^{-2}$) | %BF | FFM (kg) |
|---|---|---|---|---|---|---|
| FOB (35) | 7.17±0.78 | 1.27±0.06 | 32.80±7.93 | 20.27±3.22 | 31.51±5.04 | 22.17±3.69 |
| FLE (35) | 7.36±0.75 | 1.24±0.07 | 24.94±3.79 | 16.09±1.51 | 17.24±4.59 | 20.55±2.65 |
| MOB (35) | 7.44±0.60 | 1.29±0.07 | 34.82±6.54 | 20.80±2.40 | 29.38±4.20 | 24.38±3.57 |
| MLE (35) | 7.27±0.62 | 1.22±0.06 | 22.94±3.07 | 15.33±1.07 | 15.25±2.15 | 19.44±2.64 |
| Effect of obesity | NS | *** | *** | *** | *** | *** |
| Effect of gender | NS | NS | NS | NS | ** | NS |
| Interaction | NS | * | * | NS | NS | ** |

**Note:** FOB, female obese; FLE, female lean; MOB, male obese; MLE, male lean; NS, non significant; *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.

subject was taken. The optimal force ($F_{opt}$; N) and optimal pedalling frequency ($V_{opt}$; r/min) corresponded to the force and pedalling frequency at CPP.

### Statistical analysis

All results are expressed as mean ± SD. Age, anthropometric variables, and performance were compared using a two-way ANOVA (obesity and gender). In the case of a significant interaction, post hoc comparisons were effected using Fisher's PLSD procedure.

CPP and $F_{opt}$ were assessed in absolute terms, using ratio standards (CPP and $F_{opt}$ divided by BM and FFM). In addition, the relation between the performance variable ($Y$) and the anthropometric characteristics ($X$) were analysed using a log–linear model ($\ln Y = \ln a + b \ln X$). The allometric scaling factor ($b$ exponents) was then used to compute power functions for CPP and $F_{opt}$ ($Y = aX^b$).

For all statistical tests, the limit for statistical significance was set at $p < 0.05$. Statistical procedures were performed using StatView software.

## Results

### Anthropometry

Participants' anthropometric characteristics are summarized in Table 1. Compared with lean children, obese children showed significantly elevated values for body mass index (BMI) and %BF ($p < 0.001$ for both groups). There was a significant interaction between obesity and gender for height ($p < 0.05$), BM ($p < 0.05$), and FFM ($p < 0.01$). The post hoc comparison showed that height was significantly higher in MOB than in MLE ($p < 0.001$), but there was no significant difference between lean and obese girls. BM was significantly higher in FOB than in MOB ($p < 0.05$), but there was no significant difference between FLE and MLE. Within obese groups FFM was significantly higher in boys than in girls ($p < 0.05$), whereas no significant difference was shown between FLE and MLE.

### Cycling performance

Mean values for CPP for the two groups are presented in Table 2. CPP was significantly higher in obese than in lean children, when expressed in absolute terms ($p < 0.01$). When CPP was related to BM with a standard ratio, values were significantly lower in obese than in lean children ($p < 0.001$). When using an allometric ratio (BM $b$ exponent = 0.95 (0.68)), the difference remained significant ($p < 0.001$).

When CPP was related to FFM with either standard or allometric ratios (FFM $b$ exponent = 1.48 (0.09)) there was no significant effect of obesity.

Results for $V_{opt}$ and $F_{opt}$ are presented in Table 3. Girls showed significantly lower values for $V_{opt}$ ($p < 0.01$). There was a significant effect of obesity on $F_{opt}$, with higher values seen in obese than in lean children ($p < 0.01$). When expressed as a standard or with an allometric (BM $b$ exponent = 0.60 (0.05)) ratio with BM, obese children showed significantly smaller $F_{opt}$ than did lean children. When $F_{opt}$ was related to FFM with a standard ratio ($N \cdot kg\ FFM^{-1}$) there was a significant interaction between obesity and gender ($p < 0.05$). Values were significantly higher in FOB than in MOB ($p < 0.01$), but there were no significant differences between FOB and FLE, MLE and FLE, or MLE and MOB when using an allometric ratio (FFM $b$ exponent = 0.89 (0.07)). When $F_{opt}$ was related to FFM with an allometric ratio, only gender difference remained significant ($p < 0.05$) with significantly higher values in girls than in boys.

## Discussion

The aim of the study was to investigate the possible effects of obesity on CPP in young children with low to moderate physical activity levels. Previous authors have studied CPP in children, but not specifically in obese ones, whereas the effect of obesity in young subjects has, to our knowledge, been limited to adolescent subjects. We did not assess pubertal development in this study. We considered that, due to their young age, the children were prepubertal, although obesity is associated with early puberty, particularly in girls. As BMI does not accurately reflect changes in adipose tissue during growth, we used the newly established body fat reference curves for children to identify those with obesity (McCarthy et al. 2006). According to the International Obesity Task Force (IOTF) - BMI cut offs (Cole et al. 2000), mean BMI in FOB and MOB are just below the percentile corresponding to obesity. Although body fat reference curves were established from bioimpedance measurement, we used skinfold measurements to calculate %BF because it is practical and simple to use in field studies with trained experimenters. However, skinfold measurements underestimate %BF because skinfolds reflect only subcutaneous adipose tissue (Eisenmann et al. 2004). Thus, we cannot exclude the possibility that in the obese children studied %BF may have been higher and FFM may have been lower than actually measured.

### Effect of obesity on CPP

As hypothesized, the results showed that absolute CPP

**Table 2.** Standard and allometric models for CPP for girls and boys.

| | CPP (W) | CPP (W·kg $BM^{-1}$) | CPP (W·kg $BM^{-0.95}$) | CPP (W·kg $FFM^{-1}$) | CPP (W·kg $FFM^{-1.48}$) |
|---|---|---|---|---|---|
| FOB (35) | 181.43±49.48 | 5.57±1.10 | 6.64±1.30 | 8.12±1.43 | 1.84±0.33 |
| FLE (35) | 165.14±57.03 | 6.57±1.87 | 7.75±2.21 | 7.95±2.23 | 1.86±0.49 |
| MOB (35) | 203.43±54.94 | 5.89±1.38 | 7.05±1.64 | 8.33±1.85 | 1.81±0.41 |
| MLE (35) | 168.54±62.29 | 7.22±2.06 | 8.47±2.45 | 8.50±2.34 | 2.04±0.50 |
| Effect of obesity | ** | *** | *** | NS | NS |
| Effect of gender | NS | NS | NS | NS | NS |
| Interaction | NS | NS | NS | NS | NS |

**Note:** FOB, female obese; FLE, female lean; MOB, male obese; MLE, male lean; NS, non significant; *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.

**Table 3.** Standard and allometric models, $V_{opt}$, and $F_{opt}$ for girls and boys.

| | $V_{opt}$ (r/min) | $F_{opt}$ (N) | $F_{opt}$ (N·kg $BM^{-1}$) | $F_{opt}$ (N·kg $BM^{-0.60}$) | $F_{opt}$ (N·kg $FFM^{-1}$) | $F_{opt}$ (N·kg $FFM^{-0.89}$) |
|---|---|---|---|---|---|---|
| FOB (35) | 75.80±12.08 | 23.00±4.88 | 0.71±0.14 | 2.86±0.49 | 1.04±0.17 | 1.46±0.24 |
| FLE (35) | 76.47±17.52 | 20.57±3.65 | 0.83±0.11 | 3.00±0.41 | 1.00±0.12 | 1.39±0.17 |
| MOB (35) | 89.63±18.78 | 22.40±4.55 | 0.66±0.13 | 2.69±0.49 | 0.93±0.18 | 1.32±0.25 |
| MLE (35) | 83.40±18.53 | 19.37±4.09 | 0.84±0.14 | 2.96±0.52 | 0.99±0.15 | 1.38±0.22 |
| Effect of obesity | NS | *** | *** | * | NS | NS |
| Effect of gender | *** | NS | NS | NS | * | * |
| Interaction | NS | NS | NS | NS | * | NS |

**Note:** FOB, female obese; FLE, female lean; MOB, male obese; MLE, male lean; NS, non significant; *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.

was significantly higher in obese children than it was in lean children. This finding is in accordance with results previously obtained in adolescents (Duché et al. 2002). When related to BM with a simple ratio or an allometric ratio, CPP was significantly lower in obese children than in lean children. The exponent (0.95) calculated when CPP was related to BM with an allometric ratio was close to 1 and, as a consequence, the results were similar to those obtained with a standard ratio. CPP was related to FFM with both standard and allometric ratios and showed that the muscle ability to produce power is unaltered with obesity. In fact, the significance of comparison between groups was similar when CPP was scaled to BM or FFM with allometric and standard ratios, although the exponent for FFM-related CPP largely differed from 1 (exponent: 1.48). As cycling requires the use of muscles throughout the whole body rather than just in the lower limbs (Baker et al. 2001), we used FFM rather than lean leg volume (LLV) to express CPP. Furthermore, Doré et al. (1999) showed that FFM and LLV were similarly correlated to CPP in children. Increased sex hormone bioavailabilities in obese children leads to an accelerated growth before puberty and may explain the higher FFM in obese girls and boys (Dunger et al. 2005). Thus, the lower BM related to CPP in obese children is the consequence of a quantitative difference of BF, whereas muscle contractile properties are unaffected. Our results indicate that in obese children, altered motor performance is the consequence of an excess of fat mass and is not due to alteration of motor abilities. The lack of differences for $V_{opt}$ and $F_{opt}$ between obese and non-obese children also tends to show that cycling coordination and muscle recruitment are unaltered in obese children. This assumption would have to be confirmed by investigating the specific pattern of muscle recruitment using electromyography. Furthermore, it has been shown in obese adolescents with more severe obesity than children in our study that $V_{opt}$ was significantly lower than in lean adolescents (Duché et al. 2002). The same study showed that there was no effect of obesity on FFM-related $F_{opt}$, although absolute $F_{opt}$ was higher in obese adolescents. Hence, we cannot exclude that $V_{opt}$ could also be significantly reduced in 6- to 8-year-old children with severe obesity compared with lean children, whereas FFM-related $F_{opt}$ would remain unaffected by obesity.

### Effect of gender on CPP

Despite the lack of difference between genders for CPP in either absolute terms or when related to anthropometric variables, its two components, $V_{opt}$ and $F_{opt}$, are different in boys and girls. Our results for CPP are in agreement with Doré et al. (1999, 2005), who showed that CPP was higher in boys and girls only after the age of 13 years. This is mainly due to a higher muscle hypertrophy induced by testosterone in boys during puberty (Round et al. 1999). Although the children investigated in the present study were prepubertal, we observed that FFM-related $F_{opt}$ was higher in girls than in boys, whereas $V_{opt}$ was higher in boys. Doré et al. (2005) have also observed a gender effect for $V_{opt}$, but only in children of more than 10 years of age. Thus, our results showed that maturation of motor abilities is different in girls and boys, independent of the hormonal changes that occur during puberty. Motor unit activation, or the learning of specific pedalling coordination that may occur earlier in boys leads to several hypotheses that need verification. If this is the result of different types of physical activities, then possibly cycling-based physical activity in boys presents more unknowns than it does in girls. However, others have shown that motor ability assessed by lateral jumps was not lower in girls and that the improvement after training was even greater than in boys (Graf et al. 2004). Therefore, the reasons for lower $V_{opt}$ and a higher $F_{opt}$ in girls remain to be shown.

## Conclusion

Obese children do not perceive body mass bearing physical activities as enjoyable. Our study has shown that poor motor performance, assessed by the measurement of cycling peak power, is limited to BM-related CPP. On the contrary, obese children seem as able to perform as non-obese children when CPP is related to FFM. Owing to the excess fat mass obese children may find non-weight-bearing activities more pleasurable and these activities could be used in physical activity program designed for obese children. Differences observed for $V_{opt}$ and $F_{opt}$ between girls and boys in the absence of any differences for anthropometric variables highlight gender differences in the pattern of maturation that could influence cycling coordination, motor unit activation, muscle fiber type, or anaerobic energy production.

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