Reduction of exercise capacity in children from summer to winter is associated with lower sporting activity: a serial study

Jan Müller[1], Birgit Böhm[1], Julia Elmenhorst[1], Christiane Barta[1] and Renate Oberhoffer[1]

BACKGROUND: Declining activity in children over the past decades is thought to be one of the main risk factors for an early development of exercise intolerance and obesity. Taking this background into account, this prospective study investigated the seasonal change of children's physical activity and its association with objective measures of exercise capacity.

METHODS: A total of 96 children from two schools in Munich (42 girls, age 12.4 ± 0.8 y) underwent a cardiopulmonary exercise test (CPET) and an assessment of their daily activities (school sport, club sport, leisure sport) twice. Baseline testing was conducted in summer 2011. Follow-up examination was performed during winter 2012.

RESULTS: From summer to winter, self-reported sporting activity decreased from 10.6 ± 4.1 to 8.5 ± 4.3 h/wk ($P < 0.001$) as school sport ($P < 0.001$) and leisure sport activities ($P = 0.002$) decreased, but the activity associated with club sport did not ($P = 0.700$). In parallel, peak oxygen uptake (VO_2) declined from 102.0 ± 17.5 to 96.9 ± 17.9 % of predicted ($P < 0.001$). This decline in VO_2 was associated with a reduction in overall sporting activity ($r = 0.234$; $P < 0.032$).

CONCLUSION: Enhancing sporting activity in children during winter might be important to maintaining their exercise capacity.

Physical activity is important for metabolic and mental health in adults as well as in children (1–7). Schoolchildren should participate on a daily basis in 60 min or more of moderate to vigorous physical activity that is developmentally appropriate, enjoyable, and involves a variety of activities (4,6,8). Unfortunately, the activity levels of children (and also adults) are decreasing in our Western industrialized countries (9–11), and more than 60% of the world's population does not engage in enough physical activity (6,11). As if that were not enough, a study suggests (1) that those recommendations for daily activity were too low to reduce the clustered cardiovascular risk of children.

Regarding the seasonal change in daily activity, fewer data are available. In a recent review article (12) on accelerometer-determined physical activity data in children, only four studies (13–16) with a longitudinal design were identified. All except one (14–16) reported on significant lower activity pattern during winter. Those findings were supported in other review articles (12,17). However, whether that decrease in activity during winter was also associated with a reduction of exercise performance was not examined in the mentioned studies.

Therefore, this study aimed to compare the seasonal change in activity levels in children with their objective measured exercise performance obtained with a cardiopulmonary exercise test (CPET). Exercise capacity is positively associated with daily activity (5,18,19), and peak oxygen uptake (VO_2), the gold standard measurement of exercise capacity, has also been shown to be of predictive value in apparently healthy adults (20), as well as in patients with several diseases (20–23).

RESULTS

At baseline examination (**Table 1**), children reported to be engaged in 10.6 ± 4.1 h of sport per week. Boys were reported to be more active than girls ($P = 0.004$).

During winter, self-reported sporting activity decreased significantly to 8.5 ± 4.3 h/wk ($P < 0.001$). In a detailed analysis (**Table 2**), hours of leisure sport activities ($P = 0.002$) declined from summer to winter and the hours in school sport ($P < 0.001$) declined, as a consequence of the fact that children reached a new school class. Activity from club sports remained unchanged from summer to winter ($P = 0.700$).

In parallel, VO_2 declined from 102.0 ± 17.5 to 96.9 ± 17.9 % of predicted ($P < 0.001$), as did other parameters of exercise performance. As seen in **Figure 1**, this decline in VO_2 was associated with the reduction in overall sporting activity ($r = 0.234$; $P < 0.032$).

DISCUSSION

This study showed, by way of a longitudinal design, that the exercise capacity of children was influenced by their seasonal activity, which was significantly lower during the winter months.

Many studies (12,17), albeit almost all cross-sectional, report on the seasonal variation in the amount of daily activity in children. In concordance with our findings, the majority of the diminished activity occurred during the winter months. Girls were especially prone to be less active in comparison with boys. The reasons for reduced activity in winter might be multifactorial, but changes in weather, ecology, and hours of daylight, as well as periods of low temperatures, high rainfall,

[1]Institute of Preventive Pediatrics, Technische Universität München, München, Germany. Correspondence: Jan Müller (j.mueller@tum.de)

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Table 1. Study subjects for anthropometric data, exercise performance, and self-reported sporting activity

	Full study group (*N* = 96)	Boys (*n* = 54)	Girls (*n* = 42)	*P* value
Anthropometric data				
Sex (F/M)	42/54	54	42	—
Age (y)	12.4 ± 0.8	12.4 ± 0.8	12.4 ± 0.7	0.778
Weight (kg)	47.3 ± 10.9	46.3 ± 9.7	48.5 ± 12.3	0.351
Height (cm)	155.9 ± 9.2	156.1 ± 9.8	155.6 ± 8.5	0.805
BMI (SDS)	0.11 ± 1.14	0.04 ± 0.95	0.18 ± 1.35	0.555
Exercise performance				
Peak heart rate (beats/min)	188 ± 10.7	187 ± 12.0	188 ± 9.2	0.617
VO_2 (ml/min/kg)	41.7 ± 8.1	45.1 ± 7.2	37.5 ± 7.0	**<0.001**
VO_2 (% of predicted)	102.0 ± 17.5	98.0 ± 16.1	107.2 ± 18.0	**0.010**
Workload (watt/kg body weight)	3.5 ± 0.7	3.7 ± 0.7	3.1 ± 0.6	**<0.001**
Peak oxygen pulse (% of predicted)	104.2 ± 17.7	100.5 ± 17.1	109.3 ± 17.4	**<0.001**
Activity (h/wk)				
School sport	4.4 ± 1.1	4.5 ± 1.2	4.1 ± 0.9	0.061
Club sport	2.5 ± 2.8	3.3 ± 3.0	1.5 ± 2.2	**0.004**
Leisure sport activities	4.2 ± 2.6	4.5 ± 2.6	3.8 ± 2.5	0.229
Overall sporting activity	10.6 ± 4.1	11.6 ± 4.0	9.1 ± 3.6	**0.004**

Significant values are presented in bold.

F, female; M, male; SDS, SD score; VO_2, peak oxygen uptake.

Table 2. Children's characteristics according to the seasonal change in anthropometric data, exercise performance, and self-reported activity levels

	Baseline characteristics estimated in summer (May to July)	Follow-up characteristics estimated in winter (March/April)	Seasonal change	*P* value
Anthropometric data				
Sex (F/M)	42/54	42/54	—	—
Age (y)	12.4 ± 0.8	13.0 ± 0.8	+ 0.6 y	**<0.001**
Weight (kg)	47.3 ± 10.9	51.7 ± 11.9	+ 4.4 kg	**<0.001**
Height (cm)	155.9 ± 9.2	160.4 ± 9.8	+ 4.5 cm	**<0.001**
BMI (SDS)	0.11 ± 1.14	0.16 ± 1.14	+ 0.05	0.155
Exercise performance				
Peak heart rate (beats/min)	188 ± 10.7	187 ± 11.1	−1.2 ± 10.5 beats/min	0.276
VO_2 (ml/min/kg)	41.7 ± 8.1	39.7 ± 8.3	−2.0 ml/min/kg	**<0.001**
VO_2 (% of predicted)	102.0 ± 17.5	96.9 ± 17.9	−5.1%	**<0.001**
Workload (watt/kg body weight)	3.5 ± 0.7	3.3 ± 0.7	−0.2 watt/kg	**0.005**
Peak oxygen pulse (% of predicted)	104.2 ± 17.7	99.3 ± 16.9	−4.9%	**<0.001**
Activity (h/wk)				
School sport	4.4 ± 1.1	3.4 ± 1.4	−1 h/wk	**<0.001**
Club sport	2.5 ± 2.8	2.4 ± 2.6	−0.1 h/wk	0.700
Leisure sport activities	4.2 ± 2.6	3.0 ± 2.7	−1.2 h/wk	**0.002**
Overall sporting activity	10.6 ± 4.1	8.5 ± 4.3	−2.1 h/wk	**<0.001**

Significant values are presented in bold.

F, female; M, male; SDS, SD score; VO_2, peak oxygen uptake.

strong winds, and snow contribute to this (12). Changing environmental conditions might reflect the significant reduction of leisure sport activities as seen in our cohort. The reduction in school sport is influenced by school policy. Children spend a longer time in school than in previous years, and physical education classes have been reduced over time (6,11). Unfortunately for many children, school sports are essential for ensuring that a minimum of activity occurs. However, sport lessons are increasingly reduced with advancing school age. Our school policy is the reason why our cohort was 1 h

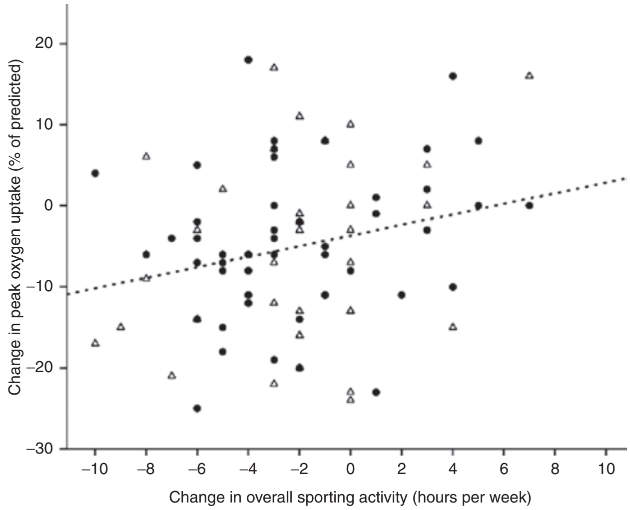

Figure 1. Seasonal change of peak oxygen uptake and overall sporting activity according to gender (solid circles represent boys; open triangles represent girls). The regression line shows that a reduction in overall sporting activity is associated with a decline in peak oxygen uptake ($r = 0.234$; $P = 0.032$).

less active in school during the winter. No seasonal influence could be observed in activities performed in a sports club. This was not surprising because club sport activities normally last throughout the year, and, for example, soccer, handball, and basketball were performed in a gym during winter.

Regarding reference values for the exercise performance, expressed as VO_2, in children there are few studies published (24–26). Today, large-cohort data are not available for children. Furthermore, longitudinal exercise studies without intervention in healthy children are completely missing. Reports (5,18) aiming to demonstrate a relation between daily activity and exercise performance have shown positive associations in children (19,27). On the one hand, our findings confirm these positive associations of activity and exercise capacity. On the other hand, our data outline that there is also a dynamic change in exercise performance throughout the seasons. This reduction in exercise performance in winter was not only obvious in the absolute values of VO_2, but also after correction of the data, which otherwise might be biased by children's natural development. However, we observed that the children had a normal development during the 6-mo period as there was no significant difference in the BMI SD scores. Therefore, the decline in VO_2 during winter may be due to a decrease in stroke volume and/or a decrease in oxygen extraction at peak exercise.

It seems comprehensible that as the current review article (12) from Rich and colleagues concluded, there is sufficient evidence to support public health interventions that aim to increase physical activity during winter. Moreover, our findings now suggest that there might be a clinical relevance to enhancing physical activity during the winter because the exercise performance in children seems to be similarly altered. School-based lifestyle approaches should be the target to increase physical activity in children as is recommended by the European Association for Cardiovascular Prevention and Rehabilitation (6).

Limitations

There are only four studies, all from Europe (13–16), on the natural history of physical activity in children, and we do not know the longitudinal activity pattern from other geographic areas. Therefore, our results and conclusion cannot simply be transferred to other countries.

In this study, a nonstandardized questionnaire was used to assess the activity status of the children, although the gold-standard tool in assessing daily activity is the accelerometer. However, the children reported twice on their activity levels, and we can assume that the error in the first estimation of their activity status is similarly reproduced in the second assessment at the follow-up examination. Nevertheless, our findings should be verified in a study using accelerometer technique for activity measurement.

Conclusion

Enhancing physical activity in children during the winter might be important to maintaining their exercise capacity. Pilot school-based projects should facilitate this by compensating for the decline in leisure sport activity by increasing school sport during winter.

METHODS

Study Subjects

From May 2011 to April 2012, 96 children (42 girls, 12.4 ± 0.8 y) from two schools in Munich were included in the study. First, anthropometric data were recorded. BMI SD score was assessed using the German LMS percentiles from Kromeyer-Hauschild and colleagues (28). Afterward, children performed a CPET on a bicycle ergometer and filled in a comprehensive questionnaire wherein they had to report on their daily activity. Study subjects are displayed in detail in **Table 1** according to gender.

The study was in accordance with the declaration of Helsinki (revision 2008) and was approved by the local ethical board (project no. 4027/11). Subjects and their guardians gave written informed consent and agreed to the anonymous publication of their data.

Exercise Capacity

All the subjects underwent a symptom-limited CPET on a bicycle ergometer in the upright position according to the international guidelines (29).

In short, after a resting time of 2 min to define baseline, subjects had a 2-min warm-up without load, followed by a ramp-wise increase of load of 10, 15, 20, or 30 watt/min depending on the expected individual physical capacity estimated by the investigator. The aim was to reach a cycling duration of about 8–12 min after warm-up. The end of the CPET was marked by symptom limitation.

The exercise test featured a breath-by-breath gas exchange analysis using a metabolic chart (Geratherm Respiratory; Ganshorn Medical, Bad Neustadt a. d. Saale, Germany). VO_2 was defined as the highest mean uptake of any 30-s time interval during exercise. Reference values for VO_2 were drawn from Cooper and Weiler-Ravell (24) and expressed as percentage of predicted. Heart rate was measured continuously using a Polar RS800CX (Polar Electro, Kempele, Finland). Peak oxygen pulse was defined as VO_2 divided by peak heart rate. The reference value was calculated from the VO_2 reference value divided by the expected peak heart rate that was estimated to be "(220 − age) × 0.925" for bicycle testing according to Rhodes and colleagues (30,31).

Subjects with a respiratory exchange ratio <1.06 or a heart rate of <85% of the predicted reference values calculated for bicycle testing ("(220 − age) × 0.925") were excluded from the study.

Activity Data

Activity data were assessed by a questionnaire. Children were asked about the time (h/wk) they participate in school sport, in a sport club, and in leisure sport activity. Those three dimensions of sporting activities were additionally summed to calculate an overall sporting activity also displayed in h/wk.

Data Analyses

All descriptive data were expressed in mean values and SD score. VO_2 was corrected for age, gender, and weight and expressed as percentage of predicted.

The comparison of anthropometric data, exercise performance, and self-reported sporting activity according to gender was performed by Student's *t*-test, whereas a paired *t*-test was used to compare baseline values with follow-up data. Associations of sporting activity and VO_2 were assessed using Pearson's correlation and illustrated by a scatter plot according to gender.

All analyses were performed using PASW 19.0 software (SPSS, Chicago, IL). For all analyses, a two-tailed P value <0.05 was considered to be statistically significant.

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