The spectrum of congenital malformations of the heart is diverse and ranges from mild cardiac changes without substantial hemodynamic relevance to severe congenital heart disease, from cardiac conditions that do not require surgery to severe, inoperable conditions. Consequently, the physical exercise capability in children with congenital heart conditions varies widely. In mild, uncomplicated cardiac malformations, exercise capability remains normal. Where the congenital heart conditions are serious, however, exercise capability is clearly reduced. However, it is not only these children who show limitations. In some children with mild or completely corrected malformations, reduced exercise capability is probably predominantly related to overprotection and the resulting lack of exercise; this can be balanced by suitable exercise training. Even doctors often advise restrictions quite unnecessarily in this setting.

Sports for children covers a wide range of activities that place very different demands on the body: from swimming for infants, gymnastics for mothers and children, leisure time play/exercise, sports in schools, sports in clubs, to competitive sports. Thus far, only few, mostly small, studies have dealt with the effects of sport on children with congenital heart disease. Without exception, these show the positive effects of sports on psychomotor development and physical exercise capacity in such children. None of the studies reported any deterioration of the hemodynamic function and/or increased health risks to the children. Larger, randomized controlled trials are urgently needed in this area.

This article aims to provide doctors practising in their own practices with information that might help them assess the exercise capacity of children with cardiovascular conditions and provide targeted recommendations about their fitness to exercise.

SUMMARY
Introduction: Children with congenital heart disease (CHD) can participate in sport on an individualized basis, if their exercise capability is formally tested. Methods: Selective review of the literature on sport in children with CHD, and analysis of the authors' own findings. Results: Few studies have addressed the effects of regular sporting activities on children with CHD. The available literature confirms that regular sport has a positive effect on exercise capacity and psychomotor development in this group of children, without any negative hemodynamic effects or additional risks. Discussion: The current internationally accepted recommendations on physical activity and sport for children with CHD are almost entirely based on diagnosis. It may however be more appropriate to classify children in terms of their current hemodynamic status. Children have a basic need for physical activity which is an integral aspect of normal somatic, motor, emotional, psychosocial and cognitive development. The majority of children with CHD following corrective surgery or definitive palliation may participate in normal sporting activities in an unrestricted fashion. Recommendations concerning sport should also be based on a hemodynamic classification, taking into account the nature of the condition, disease severity, and potential risks.

Key words: congenital heart disease, psycho-motor development, physical activity, physical performance

Klinik und Poliklinik für Kinderkardiologie, Klinikum der Universität zu Köln (Dr. med. Schickendantz); Psychologisches Institut, Universität zu Köln (PD Dr. phil. Sticker); Institut für Schulsport und Schulentwicklung, Deutsche Sporthochschule Köln (Dr. rer. nat. Dordel); Institut für Kreislaufforschung und Sportmedizin, Deutsche Sporthochschule Köln (PD Dr. sportwiss. Bjarnason-Wehrens)
In all international recommendations published thus far, the original cardiac malformation is given priority in assessing a child's fitness to exercise. It is, however, better to primarily use (postoperative) hemodynamic function and not the type of malformation for this assessment. The basis for this is a classification of postoperative (residual) findings or of the clinical conditions of children with cardiovascular disorders, as well as a categorization of these into groups by severity. The recommendations given here are based on recommendations from German and international expert societies (e1, e8, e4, e5, e13) and on longstanding experience in the treatment, sports advice, and care provided in sports activities for children with congenital heart disease.

Types of exertion in exercise
Predominantly static exercise can result in very high stress on the systemic and pulmonary circulations, which can have extreme effects on the hemodynamic function in congenital heart disease. Acute, malignant arrhythmias can result in sudden cardiac death (e6).

Predominantly dynamic sports activities, however, reduce the afterload in children with congenital heart disease and can therefore be expected to have a protective effect (14).

Box 1 gives an overview of types of exercise and games in childhood that are associated predominantly with high dynamic or static exercise.

Little is currently known about the concrete hemodynamic stress that emerges in different types of activity, e.g., during sports classes. A study conducted in Cologne showed that during games that entail much running and catching, children's heartbeat rates show high frequencies (on average 167.8 ± 17.9 beats per minute), which occasionally exceeded the maximum measurements reached during the exercise tests. The heartbeat frequency was also high when children started a new type of exercise, but fell the better they mastered the exercise (15).

Importance of sports for the development of children with congenital malformations
Children have an elementary need to move. A child's experiences of perception and movement determine not only its physical and motor development but also crucially influence its emotional, psychosocial, and cognitive development (16, e7). Heart disease often means limitations to a child's perceptive and movement-related experiences. Fears and worries for the ill child often result in the parents adopting an over-protective educational style. Fear and insecurity prevail in parents as well as in teachers and educators, especially with regard to a possible risk associated with physical exercise. Doctors often recommend restrictions, owing to ignorance. By informing and educating parents, doctors, and (sports) teachers, serious attempts will have to be made to reverse this trend. Children with congenital heart disease at risk after physical exercise will, however, have to be identified and prevented from partaking in sports.

In view of the high priority given to exercise, games, and sports in current society, participating in activities of healthy peers means improved quality of life and has a strong social and socializing aspect for children and adolescents. Being forbidden to participate in sports and/or limitations to the extent to which they can exercise is particularly disagreeable to them.
Recommendations

Many specialist societies have published recommendations on types of sport suitable for all persons with congenital heart disease (e1, 8, e5, 9, 11, 12, 13, e8, e9, 17). Physical activity in children with congenital heart disease should start as often as possible at nursery school, school, or the children’s heart group. The specific conditions and individual exercise capability/capacity have to be taken into consideration. Deficits in terms of perceptive and movement-related experiences, which might otherwise have negative consequences for the development of a child’s personality, will thus remain small or can be eradicated (7).

Demands on the muscular system should be made from infancy and during children’s preschool years. Children need to have the opportunity to live out their natural instinct and drive to move. As far as possible, they should participate without limitations in exercise, games, and sports of their peers (7, 11, 12, 13, 18, 19, 20, 21).

| Table 1 |
|-----------------|--------------------------------------------------|
| **Method** | **Aim** |
| Clinical examination | Age-appropriate development of the cardiopulmonary status and blood pressure |
| ECG at rest | Age-appropriate regularity of ECG curve |
| 24-hour Holter ECG | Regularity of cardiac rhythm over 24 hours |
| Exercise ECG with spiroergometry | Cardiac rhythm and blood pressure development under physical exertion, and cardiopulmonary fitness |
| Echocardiography | Cardiac function and hemodynamic findings |
| Exercise echocardiography | Cardiac function and hemodynamic findings under exertion |

**Box 2**

**Findings after cardiac surgery and/or interventions**

**Minor remaining findings (1.2)**
- Scar after ventriculotomy
- Incomplete right bundle branch block
- Ventriculotomy-related complete right bundle branch block
- Small residual ventricular septal defect
- Trivial pulmonary (residual) stenosis/insufficiency
- Trivial aortic (residual) stenosis/insufficiency
- Mild mitral insufficiency
- Mild tricuspidal insufficiency
- Supraventricular and ventricular singular extrasystoles
- After surgery for aortic isthmus stenosis without arterial hypertonus

**Important remaining findings (1.3)**
- Functional impairment of right ventricle
- Right ventricle = system ventricle
- Functional impairment of left ventricle
- Pulmonary (residual) stenosis (\(\Delta p>30\) mm Hg)
- Aortic (residual) stenosis (\(\Delta p>30\) mm Hg)
- Hemodynamically important AV valvar insufficiencies/dysfunctions
- Replacement valve (biologic and mechanic)
- Supraventricular tachycardias
- Ventricular tachycardias
- After surgery for aortic isthmus stenosis with arterial hypertonus
Regular, independent or guided sports activity can improve the physical and motor capacity in children with congenital heart disease. The results of empiric studies show significant improvements in coordination and skillfulness (7), stamina (21, 22, e10, e11), strength, and flexibility (22, e10, e11). In none of the studies was there any evidence of a deterioration of hemodynamic function in and/or risk to the children by the intervention program.

**Fundamentals for assessing the exercise capability of children with congenital heart disease**

To assess physical exercise capability in sports activity, the usual (pediatric) cardiologic investigations should be conducted (table 1).

In most cases, congenital cardiac malformations are corrected in infants or toddlers, using surgery or catheter interventions. Once the question of sports activity arises, a child’s physical exercise capability is then not dependent of its original cardiac malformation but on the extent of postoperative (residual) findings and functional assessment. Cardiac findings in a child with Fallot’s tetralogy, for example, after corrective surgery to close the ventricular defect and valvulotomy of the pulmonary valve, may be close to normal. Another child with Fallot’s tetralogy may, however, have significant right ventricular impairment and thus be significantly impaired in terms of its exercise capability due to pulmonary insufficiency. It is therefore not sensible to assign a particular degree of physical exercise capability to certain cardiac defects (8).

**TABLE 2**

**Group categories of pediatric cardiologic pathologies**

<table>
<thead>
<tr>
<th>Group 0</th>
<th>Patients with hemodynamically important cardiac defects before cardiac surgery/interventions (including ablations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>Patients after cardiac surgery/interventions (including ablations)</td>
</tr>
<tr>
<td>1.1</td>
<td>Without remaining findings (complete correction)</td>
</tr>
<tr>
<td>1.2</td>
<td>With minimal findings</td>
</tr>
<tr>
<td>1.3</td>
<td>With clinically significant findings</td>
</tr>
<tr>
<td>1.4</td>
<td>After palliative interventions:</td>
</tr>
<tr>
<td>1.4a</td>
<td>With separation of the circulations (e.g., Fontan procedure)</td>
</tr>
<tr>
<td>1.4b</td>
<td>Without separation of the circulations (e.g., aorto-pulmonary shunt operations)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group 2</th>
<th>Patients with cardiac defects not requiring surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Shunt defects with clinically insignificant left-right shunt</td>
</tr>
<tr>
<td>2.2</td>
<td>Clinically insignificant valvar defects/anomalies</td>
</tr>
<tr>
<td>2.3</td>
<td>Clinically insignificant cardiac arrhythmias/changes to ECG</td>
</tr>
<tr>
<td>2.4</td>
<td>Clinically insignificant myocardial changes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group 3</th>
<th>Patients with inoperable cardiac defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 4</td>
<td>Patients with chronic myocardial disorders</td>
</tr>
<tr>
<td>4.1</td>
<td>Clinically significant</td>
</tr>
<tr>
<td>4.2</td>
<td>Clinically insignificant</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group 5</th>
<th>Patients with problematic long term/permanent therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Pacemaker</td>
</tr>
<tr>
<td>5.2</td>
<td>Anticoagulants</td>
</tr>
<tr>
<td>5.3</td>
<td>Antiarrhythmics</td>
</tr>
<tr>
<td>5.4</td>
<td>Anticongestives</td>
</tr>
</tbody>
</table>

| Group 6 | Patients after heart transplantation |

Dtsch Arztebl 2007; 104(9):A 563–9 | www.aerzteblatt.de
Tables 2 and 3 and box 2 show classifications of postoperative findings or clinical findings and their categorization into degrees of severity.

Category group “0” includes patients with hemodynamically important cardiac defects before necessary corrective procedures and has been included for completeness’s sake only (table 2). For patients who have to be treated with surgical or catheter interventions, the question about sports and exercise should not be asked. This is true also for children in whom a time delay has been decided for their surgical correction, e.g., in aortic stenosis or combined aortic defects. These children are at risk from overexertion. Directly after their surgical intervention, those children are usually released from sports lessons for three to six months, until they have totally recovered. Subsequently, an individually tailored exercise program is recommended.

Patients in category groups A and B, in whom no cardiac defects or only mild residual findings exist (table 3), are not expected to show negative effects from their cardiac condition and can exercise without limitations.

Patients in group C (clinically significant remaining findings) (table 3) are able to tolerate normal physical exertion levels in everyday life. These children play with their siblings and friends without showing any signs of impairment. They are, however, impaired in terms of their maximum exercise capacity by a reduced capacity to increase their heart rate either owing to hemodynamic problems, such as valvar stenoses or insufficiencies, or to myocardial dysfunction or inadequate increase in heart rate, such as sinus node dysfunction or pacemaker therapy. Such children have to be protected from overexertion. It is recommended that such children do not pursue competitive sports and avoid types of sports with a high static load. High pressure and volume strain on pre-damaged ventricles may cause malignant arrhythmias. In the long term, an increase in myocardial dysfunction has to be expected in this setting. Recommended types of exercise include interval training at moderate intensity, e.g., ball games and running games, or moderate stamina training. Their afterload reducing effect should even result in a protective cardiac effect.

Patients with long term therapies that are problematic for sports activity – especially pacemaker implants or anticoagulation treatment – need additional recommendations. In anticoagulation treatment, patients should not indulge in any sports activities that are prone to contracting injuries. Pacemaker patients are at risk from having the pacemaker generator or the pacemaker pocket damaged in contact sports. Extreme stretching of the arms, as for example in hanging from and swinging on the still rings, may, in an unfavorable scenario – such as when the reserve loop of the pacemaker lead has been used up owing to somatic growth – cause the lead to detach.

Patients in category group D – those with severe (remaining) findings (table 3) – show severe impairments in everyday life owing to cyanosis or cardiac insufficiency. The kind of exertion and intensity of sportive activity have to be adapted to their impaired exercise capability.

Patients after heart transplantations are a special group who can be categorized in any of the groups listed here, depending on their functional status.

A patient will have to be totally banned from sports (table 4) when physical exercise results in a threat to his/her life. This is mainly the case for patients with pulmonary hypertension (8). The pressure on the pulmonary circulation can rise during exertion and result in death. Hypertrophic obstructive cardiomyopathy is an insidious disease. Patients

### Table 3

<table>
<thead>
<tr>
<th>Severity categories of pediatric cardiologic disorders</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Severity</strong></td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>D</td>
</tr>
</tbody>
</table>
often feel fit and well. Sudden death during sports activity is not rare and is often caused by undetected myocardial disease (23), as a result of hypoxia in the hypertrophic cardiac musculature. Because of the findings on auscultation – characteristic-uncharacteristic systoles – hypertrophic obstructive cardiomyopathy should not remain undetected in children who are monitored well with preventive examinations. It can present immense difficulties to tell such patients – who feel completely well – that they should not do any sports whatsoever.

The jury is out whether a sports ban is needed in patients with a long QT syndrome. Diverse molecular genetic forms of this syndrome have been recognized, and the extent of risk from physical exercise can be ascertained (24). Such expensive investigations are usually conducted in genetic centers at the request of pediatric cardiologic centers.

**Certifying fitness for sports**

The wide range of congenital heart disease makes issuing a so-called sports certificate difficult. A form that covers all forms of disease does not exist. In many children with successfully treated heart disease, an unlimited certificate for participation in sports can be issued. In a few children, however, sports has to be forbidden. The term “release from sports” should be avoided. Often, the wording “is not allowed to participate in competitive sports or primarily static exercises” is sufficient. In some, individual mention has to be made of additional limitations, such as those with pacemakers or anticoagulation treatment. It is particularly important in which setting the proposed activity will take place. The categorization in table 4 may help in assessing fitness for participation in sports exercise.

**Playful exercise**

The predominantly playful character of baby swimming or mother-child gymnastics should not result in substantial exertion for the children, but no scientific studies exist that cover this topic. Children learn the pleasure of sports exercise in a group of other children their own age. Owing to the absence of competitive pressure, leisure exercise, playing with friends and siblings, does not entail the same risks from overexertion as, e.g., sports lessons at school – especially because, in all experience, children are well able to limit their own levels of exertion through self-chosen breaks. Overworried mothers should be encouraged to leave their children enough independence for exercise and trust their child’s own judgment more.

**School sports**

At primary school, children with congenital heart disease as a rule encounter great understanding or tolerance for their situation. In secondary schools, problems may arise if teachers do not find themselves able to concede a special role to such children/adolescents. They are then not “able to bear the responsibility for the student” and suggest his or her “release” from sports lessons. Others grade exercises in which a student cannot participate owing to his or her condition, as “unsatisfactory” (the bottom grade). This increases the temptation to avoid a poor grade with the help of a doctor’s certificate. Teachers in this scenario should be encouraged to use their own judgment in allocating grades, to make participation in sports lessons attractive to such chronically ill children (25).

### TABLE 4

<table>
<thead>
<tr>
<th>Group</th>
<th>Severity</th>
<th>Category</th>
<th>Recommendation for exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Cardiac defects requiring surgery</td>
<td>0</td>
<td>No sports</td>
</tr>
<tr>
<td>A</td>
<td>No (remaining) cardiac defects</td>
<td>1.1</td>
<td>Unlimited</td>
</tr>
<tr>
<td>B</td>
<td>Mild (remaining) findings</td>
<td>1.2; 2.1; 2.2; 2.3; 2.4; 4.2</td>
<td>Unlimited</td>
</tr>
<tr>
<td>C</td>
<td>Clinically significant (remaining findings)</td>
<td>1.3; 5.1; 5.2; 5.3</td>
<td>No competitive sports</td>
</tr>
<tr>
<td>D</td>
<td>Severe (remaining) findings</td>
<td>1.4a; 1.4b; 3; 4.1; 5.4; (6)</td>
<td>Limited sports</td>
</tr>
<tr>
<td>E</td>
<td>Vitally threatening findings</td>
<td></td>
<td>No sports</td>
</tr>
</tbody>
</table>
Club sports and competitive sports
In considering the pros and cons of club sports it should be remembered that children do not meet in this setting merely for the purposes of competition. Often, the sharing of experiences in the club are priority. In such a setting, the recommendation vis-a-vis club sports should be positive. Competitive or professional sports, however, require a healthy cardiovascular system.

Rehabilitation sports / children’s heart group
The children’s heart group is a medically prescribed and supervised outpatient therapeutic service for children with congenital heart disease, which is run by a qualified sports therapist. It provides the opportunity for children to be physically active in a medically supervised “rest room.” If needed, existing psychomotor deficiencies can be examined or even eliminated, and simultaneously, the conditions can be created for a complete integration into physical activities of healthy children of the same age, as far as this is possible.

A scientific study of the Cologne children’s heart group found a significant improvement in movement coordination, measured with the physical coordination test for children (e12), as a result of the training. The motor quotient rose from 83.0 ± 16.4 to 92.9 ± 18.2 (p<0.001). The number of children with striking or impaired motor development was lowered from 63.2% to 39.9%.

For most children, participation with a time limit (90–120 exercise units) is sufficient. For children who have to be medically supervised during sports because of the severity of their disease, longer participation is desirable and sensible, to enable such children to also be physically active. The statutory health insurances fund participation in the children’s heart group with 6 Euros per exercise unit (11). Recently, a current position paper about the group has been published.

Conclusions
The eminent importance of exercise, games, and sports for the physical and motor, emotional, psychosocial, and cognitive development of children (7) makes it necessary to pay increased attention to sports activities among children with congenital heart disease. In the recommendations, as much sports as possible should be permitted and limitations should be imposed only in cases where a health risk is to be expected.

Conflict of Interest Statement
The author’s declare’s that no conflict of interest exists according to the Guidelines of the International Committee of Medical Journal Editors.

Manuscript received on 12 January 2006, final version accepted on 1 September 2006.
Translated from the original German by Dr Birte Twisselmann.

REFERENCES
For e-references please refer to the additional references listed below.

ADDITIONAL REFERENCES