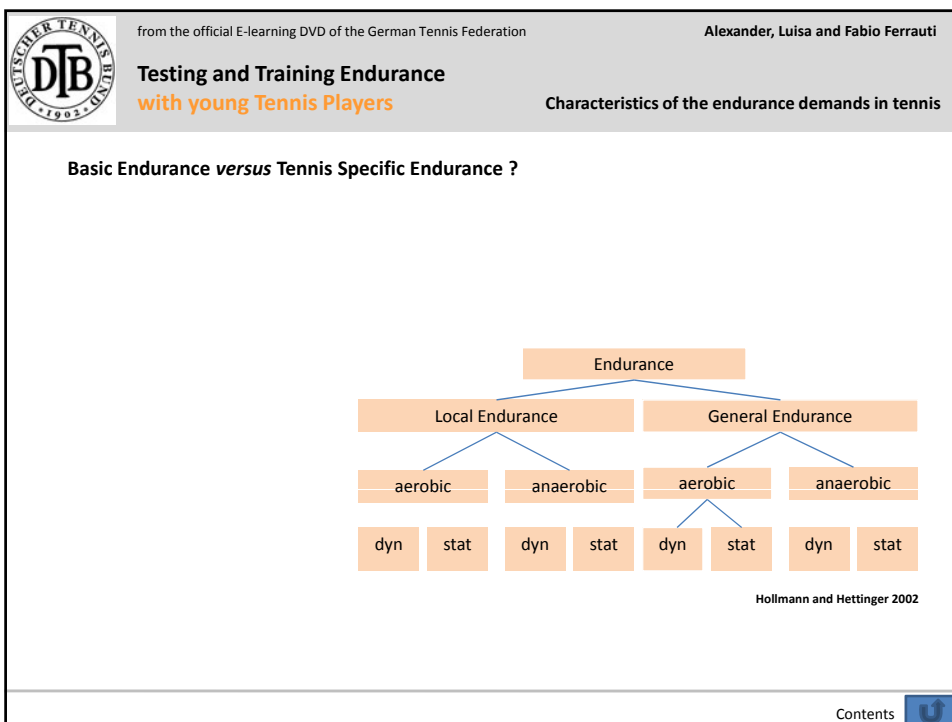
	from the official E-learning DVD of the German Tennis Federation	Alexander, Luisa and Fabio Ferrauti
	<b>Testing and Training Endurance</b> with young Tennis Players	
		<a href="#">Contents</a>
1	<b>Characteristics of the endurance demands in tennis</b>	
2	<b>Aspects of childrens exercise physiology</b>	
3	<b>Endurance training with young tennis players</b>	
4	<b>Endurance Testing: „The Hit&amp;Turn Tennis Test“</b>	



from the official E-learning DVD of the German Tennis Federation Alexander, Luisa and Fabio Ferrauti

**Testing and Training Endurance**  
with young Tennis Players Characteristics of the endurance demands in tennis

**Basic Endurance versus Tennis Specific Endurance ?**

Basic Endurance = Tolerance towards extensive aerobic, dynamic work of large skeletal muscles

**Activities:**

- Running/Jogging
- Walking/Nordic-Walking
- Cycling
- Inline-Skating
- Swimming/Aqua-Jogging
- (Nordic) Scating
- Rowing
- Aerobic/Step-Aerobic
- Indoor Fitness (e.g. Cross Trainer)
- Cardio Tennis

```

graph TD
    E[Endurance] --> LE[Local Endurance]
    E --> GE[General Endurance]
    LE --> LE_a[aerobic]
    LE --> LE_aa[anaerobic]
    GE --> GE_a[aerobic]
    GE --> GE_aa[anaerobic]
    LE_a --> LE_a_dyn[dyn]
    LE_a --> LE_a_stat[stat]
    LE_aa --> LE_aa_dyn[dyn]
    LE_aa --> LE_aa_stat[stat]
    GE_a --> GE_a_dyn[dyn]
    GE_a --> GE_a_stat[stat]
    GE_aa --> GE_aa_dyn[dyn]
    GE_aa --> GE_aa_stat[stat]
    
```

Hollmann and Hettinger 2002

Contents

from the official E-learning DVD of the German Tennis Federation Alexander, Luisa and Fabio Ferrauti

**Testing and Training Endurance**  
with young Tennis Players Characteristics of the endurance demands in tennis

Tennis Specific Endurance = ?

**Example 1:** Intensive Baseline Drill including sprints.

```

graph TD
    TSE[Tennis Specific Endurance] --> LE[Local Endurance]
    TSE --> GE[General Endurance]
    LE --> LE_a[aerobic]
    LE --> LE_aa[anaerobic]
    GE --> GE_a[aerobic]
    GE --> GE_aa[anaerobic]
    LE_a --> LE_a_dyn[dyn]
    LE_a --> LE_a_stat[stat]
    LE_aa --> LE_aa_dyn[dyn]
    LE_aa --> LE_aa_stat[stat]
    GE_a --> GE_a_dyn[dyn]
    GE_a --> GE_a_stat[stat]
    GE_aa --> GE_aa_dyn[dyn]
    GE_aa --> GE_aa_stat[stat]
    
```

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Contents

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**Testing and Training Endurance**  
with young Tennis Players Characteristics of the endurance demands in tennis

---

**Tennis Specific Endurance = ?**

**Example 2:** Volley training with high repetitions.

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Contents

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**Testing and Training Endurance**  
with young Tennis Players Characteristics of the endurance demands in tennis

---

**Tennis Specific Endurance =**  
1. *During the work*  
Tolerance towards aerobic (and anaerobic), dynamic (and static) work of larger (and smaller) skeletal muscles

Hollmann and Hettinger 2002

Contents

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**Testing and Training Endurance**  
with young Tennis Players

Characteristics of the endurance demands in tennis

**Tennis Specific Endurance =**

- During the work**  
Tolerance towards aerobic (and anaerobic), dynamic (and static) work of larger (and smaller) skeletal muscles
- After the work**  
Quick regeneration between intensiv rallies (drills) or matches (trainings units)

```

graph TD
    TSE[Tennis Specific Endurance] --> LE[Local Endurance]
    TSE --> GE[General Endurance]
    LE --> LE_aerobic[aerobic]
    LE --> LE_anaerobic[anaerobic]
    GE --> GE_aerobic[aerobic]
    GE --> GE_anaerobic[anaerobic]
    LE_aerobic --> LE_aerobic_dyn[dyn]
    LE_aerobic --> LE_aerobic_stat[stat]
    LE_anaerobic --> LE_anaerobic_dyn[dyn]
    LE_anaerobic --> LE_anaerobic_stat[stat]
    GE_aerobic --> GE_aerobic_dyn[dyn]
    GE_aerobic --> GE_aerobic_stat[stat]
    GE_anaerobic --> GE_anaerobic_dyn[dyn]
    GE_anaerobic --> GE_anaerobic_stat[stat]
    
```

**Individual Determinations of Tennis Specific Endurance:**

- Stroke energy and stroke economy
- Body weight and reactive force
- Running economy and coordination

Hollmann and Hettinger 2002

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from the official E-learning DVD of the German Tennis Federation Alexander, Luisa and Fabio Ferrauti

**Testing and Training Endurance**  
with young Tennis Players

Characteristics of the endurance demands in tennis

**Energy metabolism and oxygen kinetics differ extremely between running and tennis**

[Simulation 1](#)

[Simulation 2](#)

[Simulation 3](#)

**TENNIS**  
W.R. (VO<sub>2</sub> = 1,737 l/min)

**LAUFEN**  
W.R. (VO<sub>2</sub> = 1,695 l/min)

The figure shows two line graphs. The top graph, labeled 'TENNIS', plots oxygen consumption (VO<sub>2</sub>) and respiratory quotient (RQ) over time. The x-axis is divided into 'Rallye', 'Erholungsphase', and 'Pause' segments. The y-axis for VO<sub>2</sub> ranges from 0 to 4 l/min, and for RQ from 0.7 to 1.5. The bottom graph, labeled 'LAUFEN', shows similar data for running. The x-axis is divided into 'Rallye', '0-10 min', '10-40 min', and '100-120 min' segments. The y-axis for VO<sub>2</sub> ranges from 0 to 4 l/min, and for RQ from 0.7 to 1.5. In tennis, VO<sub>2</sub> fluctuates significantly between 1 and 3 l/min, while in running, it remains relatively stable around 1.7 l/min. RQ values are also higher and more variable in tennis compared to running.

Ferrauti et al.  
Eur J Appl Physiol 2002

**Endurance training for tennis players is based on a sufficient general endurance but has to consider predominantly the tennisspecific endurance !**

Contents

from the official E-learning DVD of the German Tennis Federation Alexander, Luisa and Fabio Ferrauti

**Testing and Training Endurance**  
with young Tennis Players Aspects of childrens exercise physiology

**Questions and Contradictions?**

„Children have a good aerobic capacity “


↑

?

↓

„Children are not made for long distance running“

**Selected Citations**




„Children have a low anaerobic capacity “

↑

?

↓

„Children love short and intense activities“

Contents 

from the official E-learning DVD of the German Tennis Federation Alexander, Luisa and Fabio Ferrauti

**Testing and Training Endurance**  
with young Tennis Players Aspects of childrens exercise physiology

**Biochemical profile**

**Anaerobic markers**

- similar resting values for muscle ATP and PCr
- lower glycolytic enzyme activity (e.g. PFK), lower adrenergic stimulation
- smaller glycogen stores, less fast-twitch muscle fibers ?
- lower maximal blood lactate concentrations
- better regulation of blood pH and blood [H<sup>+</sup>] Schwankungen

**Aerobic markers**


- quicker VO<sub>2</sub> response
- higher relative volume of muscle mitochondria and aerobic enzyme activity
- lower RER with better fat utilization


Markers	children
PCr	↔
PFK, Epi, Glyk	↓
blood [La <sup>-</sup> ]	↓
blood pH	↑
VO <sub>2</sub> -Kinetiks	↑
mitochondria Vol.	↑
RER	↓

**Interpretation**

Children seem to have a lower anaerobic and a good aerobic capacity on the first view, but this has no implications for aerobic and anaerobic fitness and endurance training!

1. The lower anaerobic capacity is adapted to body composition and body mass.
2. The biochemical aerobic capacity is not corresponding to aerobic performance.

Contents 



from the official E-learning DVD of the German Tennis Federation

Alexander, Luisa and Fabio Ferrauti

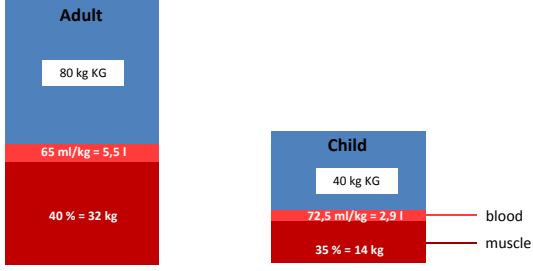
### Testing and Training Endurance

with young Tennis Players


Aspects of childrens exercise physiology


**Body composition from children and adults is different**  
 Children have a lower relative (and absolute) muscle volume and a relative higher blood volume.

**Consequently blood [La<sup>-</sup>] is lower, but this is no indication for a lower anaerobic fitness!**



Group	Weight (KG)	Blood Volume (l)	Muscle Weight (kg)
Adult	80	65 ml/kg = 5.5 l	40% = 32 kg
Child	40	72.5 ml/kg = 2.9 l	35% = 14 kg

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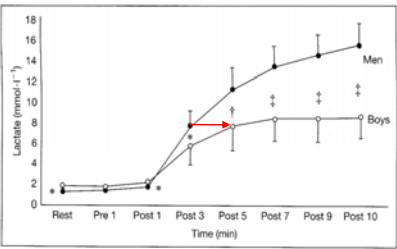
### Testing and Training Endurance

with young Tennis Players

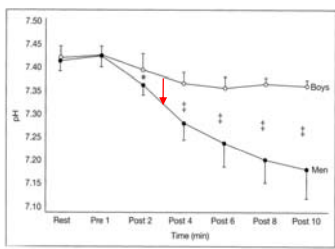
Aspects of childrens exercise physiology

**Regulation of blood pH is better in children than in adults**  
 Similar blood [La<sup>-</sup>] correspond to higher blood pH.

**Consequently children can better maintain performance during intensive repetitive work!**





Time (min)	Men	Boys
Rest	~1	~1
Pre 1	~1	~1
Post 1	~2	~2
Post 3	~8	~5
Post 5	~12	~7
Post 7	~14	~8
Post 9	~15	~8
Post 10	~16	~8



Time (min)	Boys	Men
Rest	~7.40	~7.40
Pre 1	~7.40	~7.40
Post 2	~7.38	~7.35
Post 4	~7.36	~7.28
Post 6	~7.35	~7.22
Post 8	~7.35	~7.18
Post 10	~7.35	~7.15

Ratel et al. 2002

Contents 



from the official E-learning DVD of the German Tennis Federation

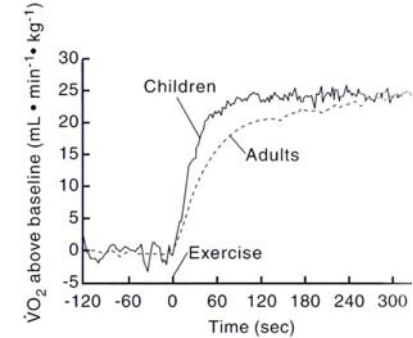
Alexander, Luisa and Fabio Ferrauti

**Testing and Training Endurance**  
with young Tennis Players


Aspects of childrens exercise physiology


**Oxygen kinetic in children is faster than in adults**  
Adaptation of oxygen uptake is regulated better at the onset of exercise.

**Consequently children have a perfect equipment for a variable oxygen uptake !**



Armon et al. 1991

Contents 



from the official E-learning DVD of the German Tennis Federation

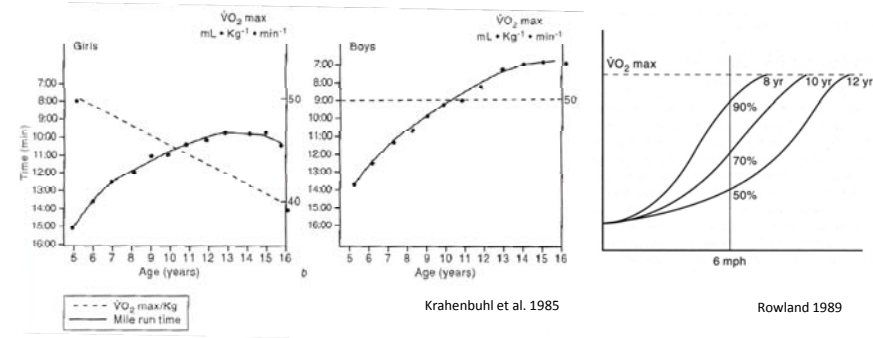
Alexander, Luisa and Fabio Ferrauti

**Testing and Training Endurance**  
with young Tennis Players


Aspects of childrens exercise physiology


**VO<sub>2</sub>max related to body weight has no indication for aerobic performance**  
Running economy in children is lower (force production, co-contractions).

**Inspite of a high biochemical capacity, the aerobic performance has biomechanical limitations!**



Krahenbuhl et al. 1985      Rowland 1989

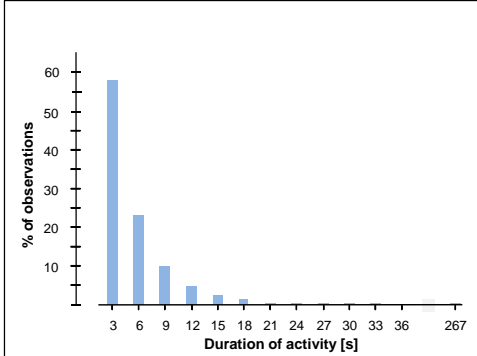
Contents 


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 Alexander, Luisa and Fabio Ferrauti

**Testing and Training Endurance**  
**with young Tennis Players**
Aspects of childrens exercise physiology


**Observational techniques show that children prefer short bursts of intense physical activity**  
 The average duration of all activities was 6 s.


**Children playing activity is partly anaerobic and aerobic and corresponds to the tennis demands!**




Duration of activity [s]	% of observations
3	58
6	23
9	10
12	5
15	3
18	2
21	1
24	1
27	1
30	1
33	1
36	1
267	1

Bailey et al. 1995

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**Testing and Training Endurance**  
**with young Tennis Players**
Aspects of childrens exercise physiology



- Children are Metabolic Nonspecialists (aerobic, anaerobic alactacid, anaerobic lactacid)
- Aerobic and anaerobic capacity (engine power) is exactly adapted to body composition (autobody)
- No risk of excessive demands because of a „physiological self restriction“
- The smaller engine has less power but produces less emissions (blood lactate)
- The musculoskeletal system (underbody of the car) is not made for long distances
- Children are perfectly suited for short bursts of intense physical activity (city traffic)

Tennis training and competition as well as a semispecific endurance training (fartlek) correspond exactly to childrens physiological, biomechanical and psychological specifics

Contents 



from the official E-learning DVD of the German Tennis Federation Alexander, Luisa and Fabio Ferrauti

**Testing and Training Endurance**  
with young Tennis Players Endurance training with young tennis players

Endurance training with young tennis players should include three categories:

**Basic  
Endurance**

**Semispecific  
Endurance**

**Tennisspecific  
Endurance**

Periodisation: modern concept of pre-season preparation

Main Season

Weeks


Contents

from the official E-learning DVD of the German Tennis Federation Alexander, Luisa and Fabio Ferrauti

**Testing and Training Endurance**  
with young Tennis Players Endurance training with young tennis players

**Tennis Fartlek**

Contents



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Alexander, Luisa and Fabio Ferrauti

**Testing and Training Endurance**  
with young Tennis Players

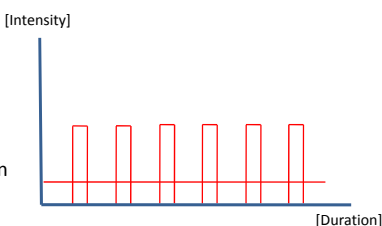
Endurance training with young tennis players


### Tennisspecific Endurance Training


**Principles:**

- Integration of tennisspecific movement patterns
- Combination of standardized and open rallies
- Integration of competitions
- Integration of speed demands
- Increase of work load intensity and stimulus duration compared to match play

**Tennis Match Play**



Contents 

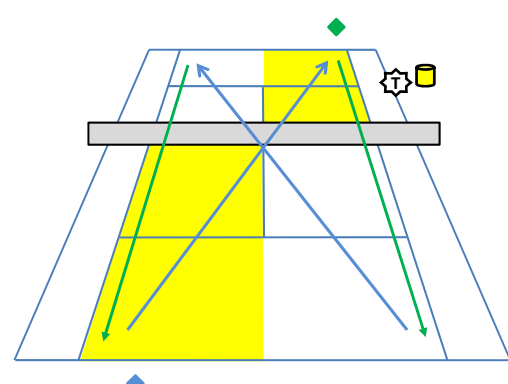


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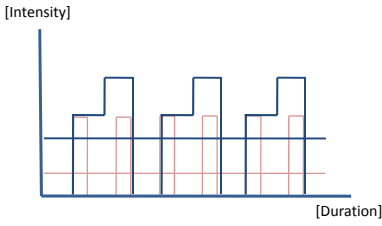
**Testing and Training Endurance**  
with young Tennis Players


Endurance training with young tennis players




**„Ins and Outs“**  
30 s „braces“  
2 points in a row

<u>Dosage:</u>	
Braces (Outs)	30 s
2 points (Ins)	30 s
Recovery	30 s



Contents 

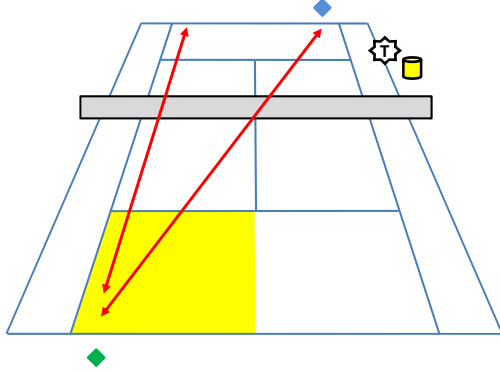


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**Testing and Training Endurance**  
with young Tennis Players

**Endurance training with young tennis players**

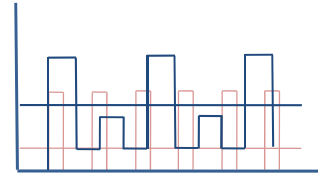


**„Under Pressure“**  
Player green plays alternating into FH and BH.  
Player blue hits into the target zone.  
Hits and errors are calculated.


Dosage:


intensive (blue)	30 s
moderate (green)	30 s
change of ends	15 s

[Intensity]



[Duration]

Contents 

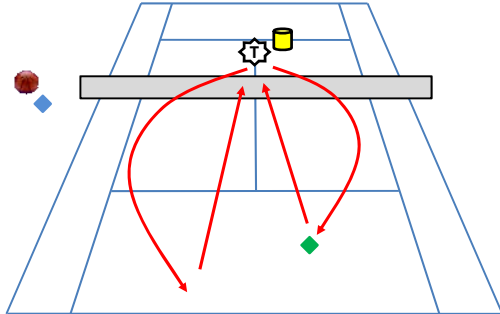


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**Testing and Training Endurance**  
with young Tennis Players

**Endurance training with young tennis players**

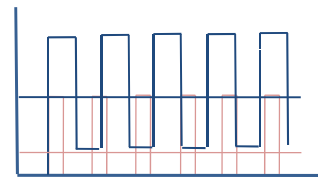


**„Bruguera“**  
The player is only allowed to play forhand and has to attack the Coach with maximum power.  
Coach plays soft and high bouncing volleys.


Dosage:


intensiv (green)	30 s
activ recovery (blau)	30 s

[Intensity]



[Duration]

Contents 

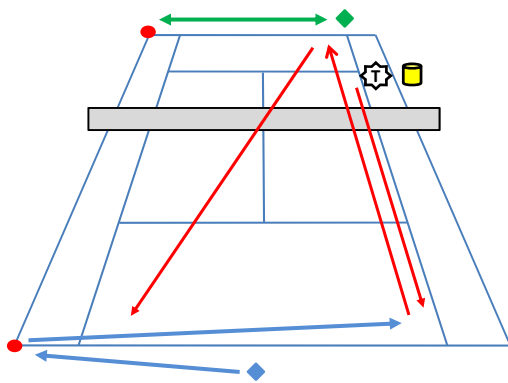


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Alexander, Luisa and Fabio Ferrauti

### Testing and Training Endurance with young Tennis Players

### Endurance training with young tennis players

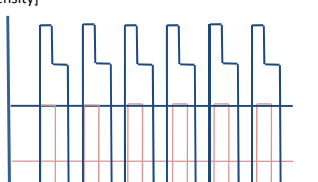


**„Baseliner after sprint“**  
 Players green and blue have to sprint after a signal .  
 The Coach feeds the ball which opens a rally between both.

**Dosage:**


Sprint	3 s
Rally	5-15 s
recovery	15 s

[Intensity]



[Duration]

Contents



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Alexander, Luisa and Fabio Ferrauti

### Testing and Training Endurance with young Tennis Players


### Endurance Testing: „The Hit&Turn Tennis Test“

**Hit & Turn Tennis Test (HTT)**

- Translation of the multistage 20 m shuttle run test (Léger 1988) on tennis demands.
- The Hit and Turn Tennis test is an acoustically controlled and progressive Fitness Test.
- The test can be easily carried out with a racket on a tennis court by one or more players at the same time.
- The object of the test is to follow as long as possible the audible signals and to hold up the required footwork.
- The player has to run along the base line and to hit a forehand or backhand shot in the respective corners just in time with the signals.
- The maximum achieved test level is assessed and can be used to estimate the maximum oxygen uptake.

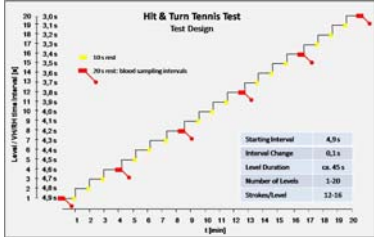
*developed by Ruhr-University Bochum (2008)  
under support of ITF and DTB*

contact: alexander.ferrauti@rub.de  
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**HIT AND TURN  
TENNIS TEST**

Ein akustisch gesteuertes Ausdauertraining für Tennisplayer zur Messung des maximalen Sauerstoffverbrauches.



Level	VO2max Interval
20	3,0x
19	3,1x
18	3,2x
17	3,3x
16	3,4x
15	3,5x
14	3,6x
13	3,7x
12	3,8x
11	3,9x
10	4,0x
9	4,1x
8	4,2x
7	4,3x
6	4,4x
5	4,5x
4	4,6x
3	4,7x
2	4,8x
1	4,9x

Starting Interval: 4,9s


Interval Change: 0,1s

Level Duration: ca. 45s

Number of Levels: 20



Stroke/Level: 22-26



Contents


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**Testing and Training Endurance**  
with young Tennis Players Endurance Testing: „The Hit&Turn Tennis Test“

**HTT test materials**




 




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**Testing and Training Endurance**  
with young Tennis Players Endurance Testing: „The Hit&Turn Tennis Test“

**HTT ball pendulum**

Ify Patel  
Tennismate  
2 Claremont Rd  
Dewsbury  
West Yorks WF13 4LF  
Tel: 00441924 459581 or 00447961 961443  
E-mail: [ifypatel@hotmail.com](mailto:ifypatel@hotmail.com)  
Price: \$59.00

Contents 



from the official E-learning DVD of the German Tennis Federation

**Testing and Training Endurance**  
with young Tennis Players


Alexander, Luisa and Fabio Ferrauti

Endurance Testing: „The Hit&Turn Tennis Test“

### HTT Norm values (male tennis players)

VO <sub>2 max</sub> [ml/min/kg]		Strokes																Category
Level	Interval [s]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1	4,9																	
2	4,8																	
3	4,7																	
4	4,6																	
5	4,5																	
6	4,4																	
7	4,3																	
8	4,2																	
9	4,1	46,0	46,0	46,1	46,2	46,3	46,4	46,5	46,8	47,0	47,2	47,4	47,6	47,8	48,0			
10	4,0	48,0	48,0	48,1	48,2	48,3	48,4	48,6	48,8	49,0	49,2	49,4	49,6	49,8	50,0			
11	3,9	50,0	50,0	50,1	50,2	50,3	50,4	50,6	50,8	51,0	51,2	51,4	51,6	51,8	52,0			
12	3,8	52,0	52,0	52,1	52,2	52,3	52,4	52,6	52,8	53,0	53,2	53,4	53,6	53,8	54,0			
13	3,7	54,0	54,0	54,1	54,2	54,3	54,4	54,6	54,8	55,0	55,2	55,4	55,6	55,8	56,0			
14	3,6	56,0	56,0	56,1	56,2	56,3	56,4	56,6	56,8	57,0	57,2	57,4	57,6	57,8	58,0			
15	3,5	58,0	58,0	58,1	58,2	58,3	58,4	58,6	58,8	59,0	59,2	59,4	59,6	59,8	60,0			
16	3,4	60,0	60,0	60,1	60,2	60,3	60,4	60,6	60,8	61,0	61,2	61,4	61,6	61,8	62,0			
17	3,3	62,0	62,0	62,1	62,2	62,3	62,4	62,6	62,8	63,0	63,2	63,4	63,6	63,8	64,0			
18	3,2	64,0	64,0	64,1	64,2	64,3	64,4	64,6	64,8	65,0	65,2	65,4	65,6	65,8	66,0			
19	3,1	66,0	66,0	66,1	66,2	66,3	66,4	66,6	66,8	67,0	67,2	67,4	67,6	67,8	68,0			
20	3,0	68,0	68,0	68,1	68,2	68,3	68,4	68,6	68,8	69,0	69,2	69,4	69,6	69,8	70,0			

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from the official E-learning DVD of the German Tennis Federation

**Testing and Training Endurance**  
with young Tennis Players

Alexander, Luisa and Fabio Ferrauti

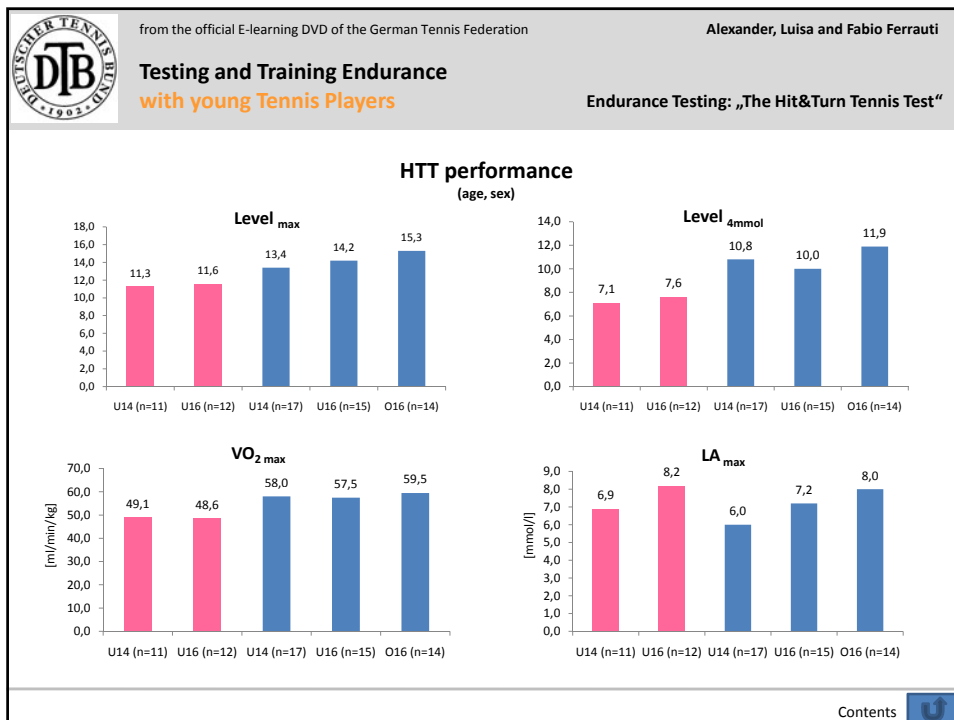
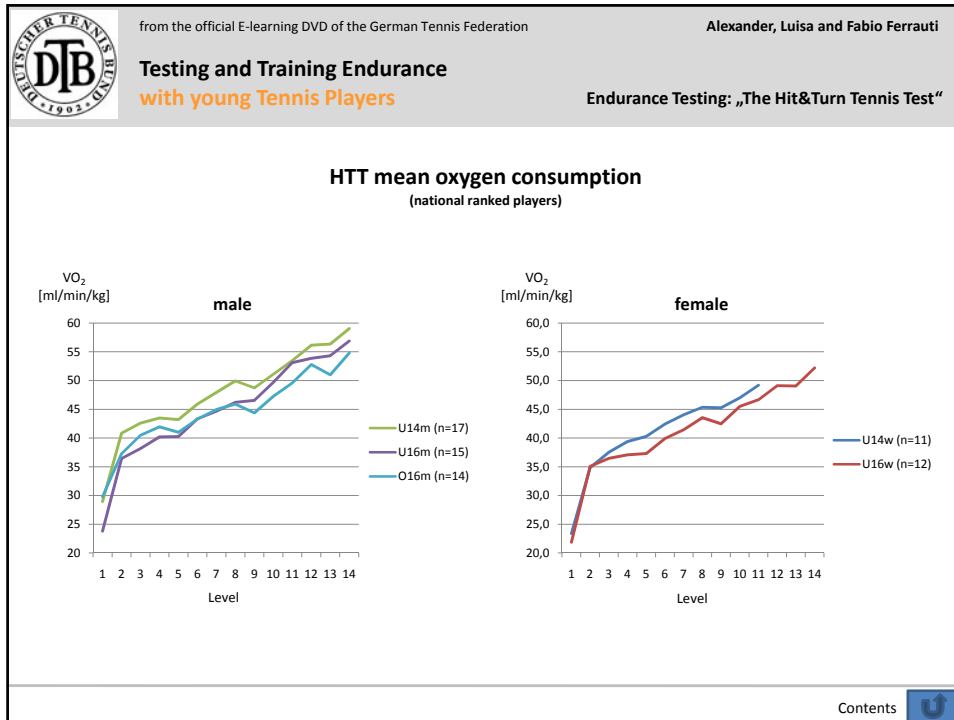
Endurance Testing: „The Hit&Turn Tennis Test“


### HTT individual value discussion

**Player R.G. (ATP 576)**  
 Test break-off: Level 17  
 VO<sub>2</sub> max: 67,0 ml/min/kg  
 4 mmol/l: Level 14,2  
**Evaluation: excellent**

**Player R.Z. (4<sup>th</sup> division)**  
 Test break-off: Level 12  
 VO<sub>2</sub> max: 51,0 ml/min/kg  
 4 mmol/l: Level 10,3  
**Evaluation: average**

Contents





from the official E-learning DVD of the German Tennis Federation
Alexander, Luisa and Fabio Ferrauti

**Testing and Training Endurance**  
 with young Tennis Players
 Endurance Testing: „The Hit&Turn Tennis Test“

### HTT Validity and Reliability


n=12		VO <sub>2</sub> max	L <sub>4</sub> mmol
Reliability	Carpet/Carpet	0,942**	0,848**
	Carpet/Clay	0,713**	0,880**
Validity	HTT/Ball Machine Test	0,961**	0,756**
	HTT/Threadmill Test	0,619 *	0,617 *




**19 €**


**HIT AND TURN**  
TENNIS TEST

Ein innovatives, professionelles Ausdauer- und Techniktest zur Abklärung der maximalen Aerobicleistung.

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THANK YOU