Functional VO_2 Considerations On Young Tennis Players

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ABSTRACT

The aim was to describe the behavior of oxygen uptake (VO_2) of tennis players in laboratory tests as well as in a match situation. 10 male players (12–22 years old) were evaluated at a maximum laboratory test during a tennis match. In laboratory, the maximum oxygen consumption (VO_2 max), production of carbon dioxide (VCO_2 max), ventilation (VE), respiratory exchange ratio (RER), heart rate (HR), and anaerobic threshold (AT) were determined. During the match, VO_2, VCO_2, and HR were measured. Laboratory data was related to the court data. At match, VO_2 max percentage was 77.75 (± 4.5) relating closely to the anaerobic threshold 85.5% (± 6.4). In conclusion, high levels of VO_2 are reached on tennis competition, so it becomes important to develop aerobic capacity to sustain prolonged matches.

Keywords: Tennis players; VO_2 during match; Anaerobic Threshold; Evaluation on court

A high VO_2 capacity allows higher intensity training and better recovery post-exercise affecting directly quality results. Tennis is an intermittent sport with many intense bouts (2–30 seconds) though this is variable, and also there are regulated rest periods between points, games and sets. The duration of a tennis match is variable and intense bouts take 15–30% of the total playing time which can last one hour minimum and in some cases more than five hours. Less intense actions prevail and there is a 1:2 to 1:5 relation between work time and rest, so the real playing time is just a lower part. On these obligatory stoppings, the ATP (Adenosine Triphosphate) and phosphocreatine (PCr) regeneration can be reached aerobically. During a set of sprints which last between 5–6 seconds, the PCr contributes around 50% of total energy supply for ATP resynthesis. PCr contribution during repeated sprints relies on the restoration of PCr waste during breaks. High energy phosphates are mainly resynthesized by oxidation at recovery time. During rallies over 10 seconds, energy supply has to be supported by anaerobic glycolysis. Average lactate concentrations during a trained-player match are between 3 and 4 mmol·L⁻¹ showing a removal ability locally oxidizing in active muscle or for being carried to other muscles for its oxidation during breaks. A poor aerobic training could produce lactate accumulation linked to poor muscle coordination and mental focus fall. Elite level players have a good aerobic capacity needed to keep high levels of motor, technical and tactical perfor-

“ Aerobic involvement seems to have an important role in the resynthesis of the system ATP-PC during required rest periods.”
formance for hours. Most of the points are within anaerobic lactic metabolism prevalence and it was thought that the \( \text{VO}_2 \) during tennis match rarely surpassed 60% of \( \text{VO}_2 \) max, however aerobic involvement seems to have an important role in the resynthesis of the system ATP-PC during required rest periods. The aim of this research was to study the behavior of oxygen consumption in elite level young tennis players in a laboratory maximum test and then in a match play situation (6 games). It was determined the \( \text{VO}_2 \) peak and \( \text{VCO}_2 \) peak by studying the relation between maximum laboratory and court values.

**MATERIAL AND METHODS**

This research had a sample of 10 male tennis players from 12 to 22 years old (mean 16.9 ±2.9), who were on an average 6 hour daily basis physical-technical training. A laboratory test on \( \text{VO}_2 \) max was carried out and then they were evaluated on court by playing 6 games facing a same level opponent.

Gases analyzer: It was used a metabolic gases analyzer VO2000, Medigraphic® along with Breeze Suite software.

\( \text{VO}_2 \) max measurement: It was performed on a treadmill Kip Machine throughout an incremental protocol. It begins with a warm-up stage, increasing speed every 1 minute with a fixed 2% slope. The test ending was due to voluntary recall due to physical exhaustion. Blood pressure was controlled every two minutes and a constant registration of electrocardiograms taken was performed.

Parameters of the \( \text{VO}_2 \) max test:

- Oxygen uptake (\( \text{VO}_2 \))
- Production of carbon dioxide (\( \text{VCO}_2 \))
- Respiratory quotient (\( \text{RER} \))
- Pulmonary ventilation (\( \text{VE} \))
- Heart rate (\( \text{HR} \))
- Anaerobic threshold (\( \text{AT} \))

\( \text{VO}_2 \) measurement on court: 6 obligatory games were played on clay court.

Both a descriptive analysis of obtained data from laboratory test and in game situation was made. In both cases, recovery processes were included. Gas data and HR were depicted regarding \( \text{VO}_2 \) max, \( \text{AT} \), \( \text{RER} \) and theoretical HR max. For data analysis was used Statistical Program IBM SPSS Statistics version 20.0 (IBM Corp.,Armor, New York).

**Bioethical considerations:** participation was voluntary and a responsible adult was present for minors care.

**RESULTS**

**Oxygen uptake and recovery on treadmill**

*Table 1* Maximal oxygen consumption on treadmill

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<thead>
<tr>
<th>n</th>
<th>Age</th>
<th>Weight</th>
<th>( \text{VO}_2 ) max</th>
<th>( \text{CFVO}_2 ) max</th>
<th>( \text{VO}_2 ) AT</th>
<th>( \text{HR} ) AT</th>
<th>( \text{RERO}_2 ) max</th>
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\( \text{CFVO}_2 \): cardiac frequency within \( \text{VO}_2 \) max, \( \text{VO}_2 \) AT: \( \text{VO}_2 \) at the anaerobic threshold, \( \text{HR} \) AT: heart rate at anaerobic threshold, \( \text{RERO}_2 \) max: \( \text{HR} \) related to \( \text{VO}_2 \) max, \( \text{HR} \) bpm: beats per minute

Relative \( \text{VO}_2 \) max on treadmill had an average of 53.09 ml.Kg\(^{-1}\).min\(^{-1}\) (±3.8) and the \( \text{HR} \) \( \text{VO}_2 \) max was 181.8 bpm (SD±10.7)

*Table 2* \( \text{VO}_2 \) recovery and HR on treadmill

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<tr>
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<th>ROT20s ( \text{VO}_2 )</th>
<th>ROT60s ( \text{VO}_2 )</th>
<th>ROT90s ( \text{VO}_2 )</th>
<th>ROT120s ( \text{VO}_2 )</th>
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\( \text{ROT} \): Recovery on Treadmill, \( \text{HR} \): heart rate, bpm: beats per minute

*Table 2* shows the recovery of the work done on treadmill on terms of \( \text{VO}_2 \) values are shown at 20 seconds (ROT20s), at 60 seconds (ROT60s), at 90 seconds (ROT90s) and at 120 seconds (ROT120s) in accordance with obligatory rest periods. Average \( \text{VO}_2 \) (ml.Kg\(^{-1}\).min\(^{-1}\) were ROT20s: 47.86 (±5.7), ROT60s: 34.94 (±4.3), ROT90s: 26.87 (±4), ROT120s: 19.98 (±3.2) and as maximum oxygen uptake percentage ROT20s: 89.93 (±6.2), ROT60s: 65.96 (±8.1), ROT90s: 50.97 (±9.2) and ROT120s: 37.63 (±7.8) were obtained.
**VO₂ and recovery on the match**

**Table 3** Oxygen consumption and heart rate peak (p) and minimal (min) on the match

<table>
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<tr>
<th></th>
<th>VO₂p (ml/kg/min)</th>
<th>VO₂p%M %</th>
<th>VO₂p%M %</th>
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<td>186</td>
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<td>44.0</td>
<td>125</td>
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VO₂p%M: VO₂p as percentage of VO₂max, VO₂p%M: VO₂p as percentage of AT.
HR: heart rate

Average VO₂ peak values were of 41.37 ml/kg·min⁻¹ (SD: 3.7), showing 77.75% (SD:4.5) of VO₂ max obtained on treadmill (see Figure 1). HRp was 185.9 bpm (SD:17.7), showing 91.57% of average theoretical HR.max (SD:8.3). Average low VO₂ was 20.01 ml/kg·min⁻¹ (SD:3.4) representing 37.77% (SD:7.5) of low VO₂% max (see Figure 1). The average minimum HR (HRmin) was of 135.7 bpm (SD:5.5) representing 73.55% (SD:6.3) of HR on VO₂ max and 66.83% (SD:2.9) of HR max.

**DISCUSSION**

Tennis is an intermittent and irregular sport though there is a maximum score agreed beforehand. Although actions may last from 2 to more than 30 seconds, breaks have their own rules related to duration. In a game density may vary from 1:15 to 1:1. There are standard tests for tennis players, for instance the Hit & Turn Tennis Test, an adaptation of Course Navette, which is constant and progressive. But these aspects are not typical of tennis and even though a racket is used and is played on a court, they share very few things. In addition, energy expenditure represented by strokes is not considered since they are simulated. The upper body is greatly involved in tennis strain. Movements, repeated and high intensity impact are an important predictor of the VO₂. Because of this, it was decided to evaluate what was going on in a court during a match. These are unique and incomparable situations, but are the real ones. According to the reports of Smeakal et al., Fernández Fernández et al. and Murias et al., values have been informed as set average. However this may not properly represent what happens during the match. Fernández Fernández et al. found that on training, when performing forehand cross court for 5 minutes, VO₂ average requirements are greater than those of the match: 34.7±2.2 ml/kg·min⁻¹ versus 26.6±2.3 ml/kg·min⁻¹. This happens as forehand cross court work is constant and the match is intermittent having 20-second rest between points and 90-seconds rest when there is a change of sides. It is not proper to compare constant and intermittent actions with the same analysis method (VO₂ average value). Thus, it was decided to take maximum values as characteristics of strain and minimal ones as recovery during game rests. The maximum average value was 41.27 ml/kg·min⁻¹ (±3.7) representing 77.75% (±4.5) VO₂max. These figures are close to 47.8 ml/kg·min reported by Smeakal et al., who suggest that match energy demand is greatly influenced by rallies duration and express that this may be a guide to evaluate needed endurance capacity to sustain high intensity periods on matches. Proper aerobic fitness is required for players who play from baseline keeping long points.

On recovery, average low VO₂ was 20.01 ml/kg·min⁻¹ (±3.4) representing on average 37.77% (±7.5) of the VO₂max (VO₂low%M) similarly to treadmill recovery occurred 2 minutes later of stopping highest exercise (ROT20s), 19.8 (±3.2) ml/kg·min, and as a VO₂ max percentage: 37.63 (SD:7.8). Regarding game intensity, it can be interesting that during the match values are close to VO₂max AT on maximum test: 95.56% (SD:6.4), accounting that competition is being held practically on AT level. This metabolic transition moment is also reflected, on average, in the RER: that is close to AT value; that is 103.5% (SD:12.2). HR during match reaches high values and on average it was of 185.9 bpm (SD:17.7), higher than average HR at VO₂ max on treadmill which value was of 181.8 bpm (SD:10.7). This is so due to typical agonist components. HR during the match is higher than of the AT: 112.7% (SD:12.8). Lowest average value was of 135.7 bpm (SD:5.5) representing 73.55% (SD:6.3) of HR at maximum oxygen uptake time.

Training benefits are higher when game situation is closely recreated; that is being as specific as possible. Anaerobic alactic, glycolytic and aerobic energy systems must be trained. A high-level cardiorespiratory fitness may avoid fatigue and help to recover between game intervals, matches or tournaments. A high aerobic capacity is required during the match and also to hold a tournament season. It is recommended that a tennis player reaches a VO₂ max above 50 ml/kg·min⁻¹. In this research, VO₂max on
trademill had on average 53.09 mL.kg⁻¹.min⁻¹ (SD=3.8) matching with the competitive level of studied players.

There is a strong relationship between aerobic and anaerobic capacity in elite level tennis players as a result of intermittent and highly intense nature of this sport. The aerobic contribution on the first 6 seconds of a 30 second-maximal sprint is of 9%; PCR resynthesis and the elimination of intracellular inorganic phosphate concentration are oxygen-dependent processes. Players having a good aerobic capacity are more capable of making high-quality repeated sprints improving the anaerobic system. A high VO₂ max value could be of use to build anaerobic capacity; and it is possible (and desirable for tennis) to have high aerobic capacity values matching high anaerobic capacity values.¹³

Thus, there must be different associated training methods linked to two issues: firstly, to activities and typical distances used in the category in which the player is training for (it is required to be a good viewer and have a consistent registry); secondly, linked to physical and technical level ability of the athlete. This means that training should always be intense (at least on match speed), on reasonable time (related to points and games common duration), to correctly administer rest intervals: micro, 20 seconds; macro, 90–120 seconds. Finally, technical training on court may have an important impact on tennis player fitness.¹⁴ This is important when considering technical work as a physical stimulus that should be taken into account on a daily basis work load. Physical training may contribute to form a better tennis player but technical work acts always on tennis player physical condition.

CONCLUSIONS

This research studied the behavior of VO₂ in high-performance young tennis players in a controlled laboratory situation where maximum values of oxygen uptake and heart rate were obtained. Then, the same players, in a ruled game situation were studied defining relation between maximum values and what was registered at the court. On average, this value was of 77.75% (SD=4.5) out of VO₂ max and closely related to the anaerobic threshold value, 95.56% (SD=6.4), showing that aerobic capacity is important in tennis which is characterized mainly by anaerobic situations repeated over a many-hour match. It is recommended that a tennis player physical training plan accounts for time devoted to improve aerobic condition.

References

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