ORIGINAL ARTICLE

Physical performance changes after unsupervised training during the autumn/spring semester break in competitive tennis players

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Background: All competitive tennis players take time away from coaches throughout the year; however, little information is available as to the short-term physiological effect of these breaks.
Objective: The purpose of this investigation was to evaluate the impact of a 5 week off-campus structured, yet unsupervised, break from regular training in top collegiate tennis players.
Methods: A nationally ranked collegiate NCAA Division I male tennis team (n = 8) performed a test battery in December and again in January after a 5 week period of recommended, yet unsupervised, training. The tests performed were 5, 10 and 20 m sprints, spider agility test, medicine ball power throws, standing long jump, Wingate anaerobic power test, VO_{2max}, push-up and sit-up test, grip strength and range of motion (ROM) measures (goniometer) of the shoulder, hip, hamstring and quadriceps.
Results: Paired t tests ($p<0.05$) showed significant decreases in mean (SEM) Wingate power measurements in Watts/kg (pre: 8.35 (0.19) w/kg ; post: 7.80 (0.24) w/kg), minimum Wingate power (pre: 5.89 (0.27) w/kg; post: 5.10 (0.38) w/kg) and VO_{2max} values (pre: 53.90 (1.11) ml/kg/min; post: 47.86 (1.54) ml/kg/min). A significant increase was seen in the athlete's fatigue index (pre: 44.26 (2.85)%; post: 51.41 (3.53)%), fastest 5 m (pre: 1.07 (0.03) s; post: 1.12 (0.02) s), 10 m (pre: 1.79 (0.03) s; post: 1.84 (0.04) s) and 20 m (pre: 3.07 (0.05) s; post: 3.13 (0.05) s) sprint times. No significant differences were seen for the other variables tested.
Conclusions: These results suggest that a 5 week interruption of normal training can result in significant reductions in speed, power and aerobic capacity in competitive tennis players, likely owing to poor compliance with the prescribed training regimen. Therefore, coaches and trainers might benefit from techniques (eg, pre- and post-testing) requiring athletes' to have accountability for unsupervised workouts.

Training for competitive tennis requires year-long training in all aspects of physical performance. Throughout the training cycle, there will be periods where the athlete will be away from the home facility, coaches and medical staff and could reduce training volume or intensity without continual supervision. This period is not usually designed for competitive tournaments, yet substantial training is still planned and expected. The US Collegiate tennis environment provides opportunities to study these short-term breaks from regular supervised training. The collegiate tennis season is divided into three distinct periods: autumn, spring and summer. Autumn (August–December) is the traditional pre-season where training is designed to improve performance variables and training volume is high. Spring (February–May) is the major competition period. Between the autumn and spring, most programs allow their athletes to leave campus to see family and friends during the 3–5 week break period. This time period will be referred to as the ''break''.

A number of physiological variables are important in tennis play including speed, agility, strength, muscular endurance, anaerobic power, aerobic capacity and joint specific flexibility.[1–3] These are variables that could result in impaired performance if inadequate training takes place over the break that would result in performance akin to detraining.

It has been shown that maximal measures (VO_{2max}, speed) can be maintained up to 28 days with a reduced training volume of 70%–80% of pre-reduction training.[4] If the athletes perform less than is required to maintain these values, aerobic capacity (VO_{2max}) can decline between 4–14% in as little as 4 weeks.[5]

Power output has been shown to be reduced in as little as 3 weeks of strength training cessation.[6] However, single movement explosive activity (vertical jump) has been shown to no be affected by 6 weeks cessation of training.[6]

To date, no data are available describing the tennis athletes' physiological response to a typical off-campus autumn/spring break period. Therefore, the purpose of this study was to observe how unsupervised, yet ''prescribed'' training (3 days a week strength training program and 2 day/week speed and conditioning program) during a 5 week period between the autumn and spring seasons could impact physiological variables in high level NCAA Division I collegiate male tennis players' upon returning to campus.

METHODS

Procedure

Each participant completed a series of tests performed during a week-long period in December (pre) and then repeated in January (post) after 5 weeks of prescribed, yet unsupervised off campus training. During each testing period (pre and post) each participant completed three separate testing sessions. Session 1 in both cases was a speed and power testing session focusing on movements utilised during tennis play at an indoor tennis facility (~18–22°C), while sessions 2 and 3 were counterbalanced for the pre session with the order replicated within individuals for the post session. Sessions 2 and 3 were laboratory testing of range of motion (ROM), aerobic endurance

Abbreviations: ASIS, anterior superior iliac spine; ITF, International Tennis Federation; ROM, range of motion; SLJ, standing long jump

(VO_{2max}) testing session and a muscular endurance/anaerobic power (30 s Wingate cycle test).

Participants

All participants (n = 8) for this study were elite level male collegiate tennis players recruited from a nationally ranked NCAA Division I men's tennis program in the Southeastern USA. Players were all previously nationally ranked juniors and one of them ranked in the top 100 International Tennis Federation (ITF) junior rankings. Prior approval was obtained from the Institutional Review Board (IRB) for Human Subjects.

Measurements

Height, weight and body fat % were measured. Body fat percentage was estimated at three sites (chest, abdomen, thigh).[7]

Internal/external shoulder ROM

Procedure for measuring internal and external ROM has been published previously.[8] Total rotation range of motion (TotalROM) was calculated by combining the maximal internal and external rotation measurements for each extremity independently, which provides a left and right TotalROM value.[9 10]

Hamstring ROM

The participants lay supine on the examination table with a neutral spine position. The leg not being tested was kept on the table with the knee completely straight. The examiner raised the testing leg while monitoring the player's anterior superior iliac spine (ASIS) of the pelvis. The leg was raised passively until motion was felt or observed at the ASIS. The hip flexion angle was measured with a goniometer, landmarked at the lateral aspect of the hip joint using the greater trochanter of the femur as a reference. The other lever was positioned on the lateral midline of the femur.

Quadricep ROM

Participants lay prone on a table and the goniometer was set so that the stationary arm was aligned with the greater trochanter; the moving arm was aligned with the fibular head and lateral malleolus. The axis was placed over the lateral femoral epicondyle. Passive ROM in the sagittal plane was then assessed with the involved knee beginning at 90° from the table (horizontal) and then the participant was instructed to flex the knee while maintaining a neutral spine.

Hip test (Patrick's test)

The testing protocol used in this study to determine the range of motion associated with Patrick's test has been used previously.[11]

Sit and reach

Lower back and hamstring flexibility was measured using a standard sit and reach test.[12–14]

Maximal push-up test

Maximal push-up test protocol has been described in previous work and proper form was stringently enforced.[14]

Sit-up test (1 min)

Participants used a bent-knee sit-up technique with hands interlocked behind the head and flexing at the trunk and hip until the elbows touched the thigh. The participant then completed as many sit-ups as possible in 1 min. A sit-up was considered complete when the athlete touched the thigh.

Handgrip

A standard hand grip strength dynamometer (JAMAR, J.A. Preston Co., Jackson, Missouri, USA) was used to measure dominant and non-dominant hand grip strength in the standing position according to previously described methods.[15]

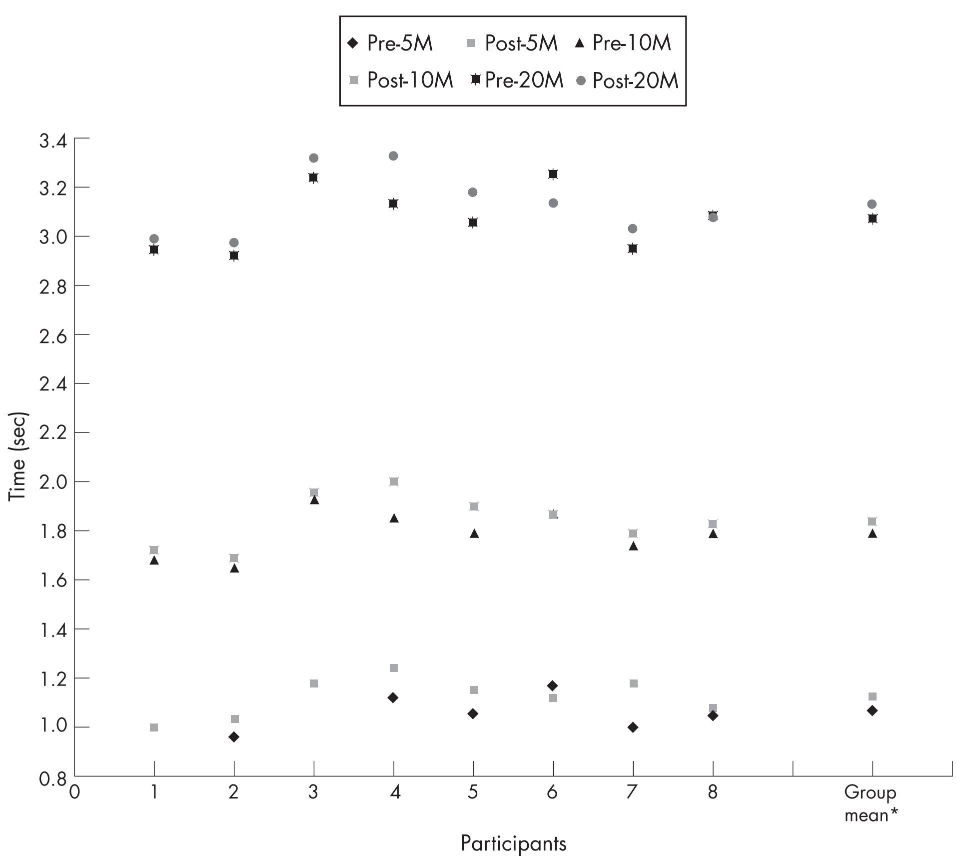

Figure 1 Pre- and post-break 5, 10 and 20 m sprint results. Group means were significantly different ($p \leq 0.05$).

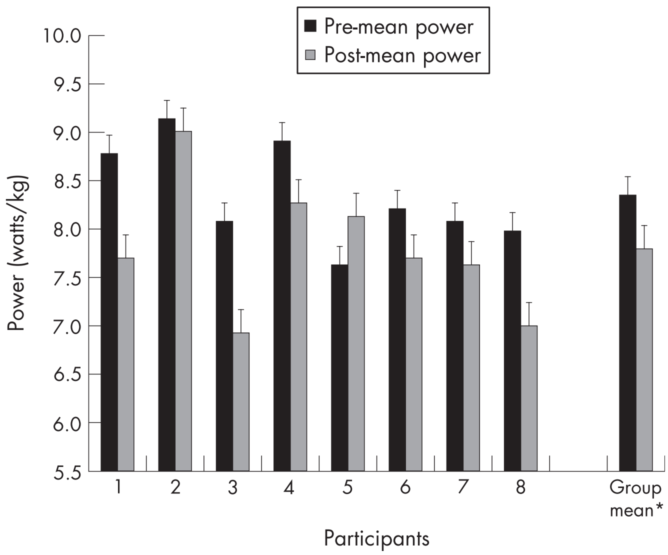

Figure 2 Pre- and post-break mean Wingate power. Group means were significantly different ($p \leqslant 0.05$).

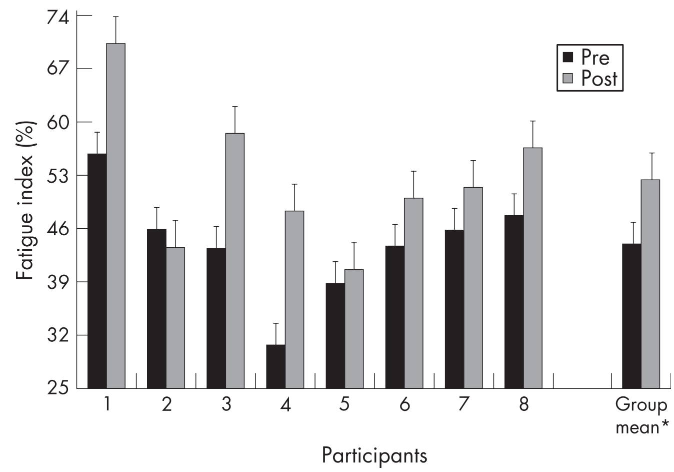

Figure 3 Pre- and post-break fatigue index results. Group means were significantly different ($p \leqslant 0.05$).

Sprints (5, 10 and 20 m)

Sprint times were recorded using four sets of two electronic photo cells (Speedtrap II, Brower Timing Systems, Utah, USA) placed at 0 (start), 5, 10 and 20 m. Times for each distance were recorded to the nearest 0.01 s via telemetry to a handheld system for each of the sprints. To control for error, the laser beam was positioned so the height above the ground approximated the centre of mass of the participants.[16]

Standing long jump (SLJ)

SLJ represents an explosive type of movement, which correlates well with other types of explosive movement such as the vertical jump.[16] In-depth procedures have been explained previously.[16]

Medicine ball power throw 9 kg (20 lbs)

A brief description of proper form, was provided to all participants verbally and visually. With feet shoulder width apart stance the participants grasped a 9 kg (20 lbs) medicine ball (MB) with both hands, flexed both knees and took the MB below the knees and exploded forward and upward while releasing the MB in a forward direction attempting to achieve maximum horizontal distance. Each participant performed three trials each separated by 3 min recovery[17] and the farthest throw was used for analysis.

Medicine ball service motion throw 4.5 kg (10 lbs)

The protocol for this test has been described previously.[13]

Wingate anaerobic power test

The Wingate anaerobic power test was performed on a cycle ergometer (Monark Ergometer Model 824, Varberg, Sweden).[18] Seat height was adjusted so that knees were slightly bent (~10–15°) when the pedal of the same side was at its lowest position during a revolution. Participants performed a 2 min warm-up at a self-selected resistance and cadence. Participants were instructed to pedal as rapidly as possible with maximal effort against the inertial resistance of the flywheel, with resistance being applied (0.736 N/kg body mass) to initiate the test. Participants were required to remain seated throughout the 30 s bout, and verbal encouragement was provided throughout the bout. A computer interface measured flywheel revolutions. Peak power was determined as the highest 5 s segment. Mean power was computed using the total number of revolutions for the 30 s bout. The lowest 5 s segment determined minimum power. The fatigue index was calculated by dividing the minimum power output by the peak power output and expressing this value as a percentage.

Spider agility test

The spider agility test was performed on a standard tennis court and involved a timed run to retrieve five tennis balls and place them in a rectangle behind the centre of the baseline previous published protocol was followed.[1 13]

Statistical analyses

Data analyses were performed using dependent (paired samples) t test to determine significant differences in pre- and post-break results. The level of significance was set at $p \leqslant 0.05$.

RESULTS

The mean (SEM) height of the participants was 183.70 (2.27) cm. The average body mass was 76.81 (2.23) kg and the average percent body fat was 7.71 (1.48)%.

Significant differences were observed in sprint speed (5, 10 and 20 m sprint times) and Wingate power measures (figs 1–3) and VO_{2max} values (table 1). ROM values are presented in table 2. No significant differences were found in any of the flexibility measures between pre and post tests. No significant differences were found in dominant/non-dominant grip strength, sit-ups and push-ups. However, a downward trend approaching significance was observed in grip strength for the dominant side ($p = 0.095$) and the non-dominant side ($p = 0.070$).

DISCUSSION

The purpose of this study was to assess changes in physical variables in a nationally ranked NCAA Division I men's tennis team before (pre) and after (post) a 5 week unsupervised, yet prescribed program (3 days/week strength training program and 2 days/week speed and conditioning program, see table 3), which was performed off-campus during the break between the autumn and spring semesters.

The results showed significant decreases in speed, power and aerobic capacity, but no difference in anthropometric measures, ipsilateral ROM, muscle endurance, agility and grip strength. These results suggest that a detraining effect had taken place in vitally important physical components for tennis players. It has been shown previously that most physiological variables can be

Table 1 Pre- and post-break values for speed, power, muscular endurance and aerobic capacity

	Pre	SEM	Post	SEM	p Value
SLJ (m)	2.42	0.06	2.40	0.05	0.55
MB throw (m)	7.50	0.19	7.69	0.20	0.30
MB service throw (m)	8.63	0.33	8.83	0.33	0.29
Spider (sec)	16.50	0.17	16.72	0.18	0.17
5 m sprint (sec)	1.07	0.03	1.15	0.02	0.04*
10 m sprint (sec)	1.79	0.03	1.84	0.04	0.02*
20 m sprint (sec)	3.07	0.05	3.14	0.05	0.03*
Wingate peak (watts/kg)	10.62	0.28	10.52	0.20	0.40
Wingate mean (watts/kg)	8.35	0.19	7.80	0.24	0.03*
Wingate minimum (watts/kg)	5.89	0.27	5.10	0.38	0.02*
Fatigue index (% decrease)	44.26	2.85	51.41	3.53	0.01*
Grip dominant (kg)	53.13	1.79	55.00	2.14	0.10
Grip non-dominant (kg)	46.00	2.28	48.63	2.57	0.07
Sit up	42.88	1.52	44.50	2.22	0.27
Push up	37.00	2.41	37.25	3.21	0.90
VO_{2max} (ml/kg/min)	53.90	1.11	47.86	1.54	0.001*

* significance $p \leqslant 0.05$

maintained up to 28 days with reduction in training to approximately 1/3 of pre-reduction levels.[19]

The significant mean reduction in VO_{2max} of 6.04 ml/kg/min was an 11% reduction from the pre to post trials. This 11% reduction of VO_{2max} is within the range that is seen in the detraining literature.[5] A review[20 21] of studies with less than 4 weeks of detraining has shown reductions in VO_{2max} between 4–14%. This decline in cardiovascular function seen during detraining is attributed to a reduction in stroke volume that is a consequence of the reduced blood volume.[5] Short-term cardiorespiratory detraining is often characterised by a rapid decline in VO_{2max} in highly trained athletes, but a smaller reduction in recently trained individuals.[20 21] As all the athletes in this study were highly trained, the results supports previous data suggesting that these athletes detrained.

Speed values for the 5, 10 and 20 m sprint speed times all were significantly slower compared to the pre-break trial. The majority of points during a tennis match last less than 10 s with the average point between 4–7 s.[22 23] Therefore, the distance and times measured during this speed trial might have important implications on performance. If athletes' speed over less than 20 m is reduced during these unsupervised breaks, this would suggest that their on-court performance would be reduced due to the inability to effectively chase down balls and/or set up for shots as quickly as other athletes who are able to maintain or improve speed levels. It has been reported that significant decreases in II (fast-twitch) muscle fibre size in trained anaerobic athletes can occur in as little as 2 weeks of detraining.[24] Even though the sprint trials (<4 s) showed a significant reduction in performance, the spider agility test did not show a statistically significant difference from pre to post trials. Low to moderate correlations ($r = 0.032$ to 0.642) were found in a recent study looking at the specificity of speed and agility in tennis players.[25 26] These results have also been supported in trained soccer players.[26] The differences have been speculated to be a result of the musculature recruited, in the requirements for strength to be developed at specific muscle lengths, in the requirements for strength to be developed in either shortening or lengthening contraction modes, or in the complex motor control and coordination of several muscle groups.[25 26] Another possible explanation for this is that the 5, 10 and 20 m sprints, that were all less than 4 s in duration, were measuring pure linear speed and were requiring a predominant focus on stored intramuscular ATP and phosphocreatine for energy production, whereas the spider agility test (which lasted between 16–18 s), relies heavily on energy from glycolytic ATP turnover. That is, we believe the different energy system required by tests of dissimilar duration could have been affected differently by the 5 weeks of reduced training.

Power measures in this study showed somewhat mixed results. The SLJ and two medicine ball throws did not show significant differences, yet mean and minimum power (as measured via the Wingate anaerobic power test) was significantly reduced, which led to a significant increase in the fatigue index (7.15%) (fig 3).

Table 2 Pre- and post-break ROM values

	Pre	SEM	Post	SEM	p Value
Body fat (%)	7.54	0.83	7.89	0.65	0.66
Weight (kg)	76.98	1.58	76.65	1.94	0.53
Sit and reach (cm)	27.38	1.74	28.88	1.85	0.08
Quad dominant	36.63	2.07	36.88	2.07	0.90
Quad non-dominant	35.25	3.35	33.00	3.33	0.08
Hamstring dominant	61.13	4.86	63.63	5.87	0.24
Hamstring non-dominant	63.13	3.43	66.00	3.40	0.26
Hip dominant	23.25	1.42	23.31	2.28	0.97
Hip non-dominant	21.38	2.00	23.94	1.55	0.22
Shoulder int. dominant	35.88	6.17	39.50	2.87	0.56
Shoulder int. non-dominant	46.50	5.85	45.13	4.59	0.81
Shoulder ext. dominant	90.88	6.69	83.63	4.36	0.15
Shoulder ext. non-dominant	87.00	6.15	100.00	4.86	0.12
Shoulder dominant (total)	126.75	11.19	121.00	4.85	0.58
Shoulder non-dominant (total)	133.50	9.32	147.30	6.75	0.26

All values in degrees (˚) unless noted.

Table 3 Structured physical workouts during break for men's tennis programme

	Monday	Wednesday	Friday	Tuesday/Thursday
1	Complex I ×1 series	Complex III ×1 series	Complex I ×1 series	Warm-up and stretch
2	Hang snatch 1×5 1×4 2×3	Hang clean 1×5 3×4	Hang snatch 3×5	Jump rope 5×100 reps (2 leg hop, 1 leg hop, running, jumping jack, two swings per jump)
3	Clean pull (from rack above knee) 3×5	Snatch pull (below knee) 3×4	Step ups 3×8+8	5–10–15 shuttles ×5 (rest 30 s between)
4	Back squat 1×10 (135) 1×8 1×6 2×4	Lunges 4×8+8	RDL 3×8	Tempo: 10×100 s
5	RDL 3×8	Leg curl 3×8	Dips 4×8 (w/weight if possible)	Rest 90 s between jump rope and shuttles, and between shuttles and tempos
6	Bench 1×10 1×8 1×6 2×4	Incline 1×10 1×8 2×6	Lat pulldown 4×8	
7	Chins ×20 total reps	Bent over row 3×8	DB shrug 3×15	
8	Military 3×8 (medium)	Three way shoulder (lat raise, ft. raise, bent over lat raise) 3×8+8+8	Goodmorning 3×6 (keep weight light and form perfect)	
9	Hyperextension 1×20	Reverse Hyper 1×20	Abs: 100 total reps (medium intensity)	
10	Abs: 100 total reps (medium intensity)	Abs: 100 total reps (medium intensity)		

However, peak power did not show a difference between pre and post trials. A plausible explanation is that the all out maximal single (SLJ, MB throws) or very short (5 s peak Wingate value) power outputs, are not affected by the apparent detraining. A similar outcome was found in strength trained athletes who showed a reduction in Wingate performance with 3 weeks of training cessation.[6] However, single movement explosive activity (vertical jump) was not affected by 6 weeks cessation of training.[6] An explanation for why this might occur has been associated with the acid-base buffering system, whereby power output might be negatively affected by an acidic environment.[24]

Anthropometric measures did not show significant differences between the pre and post trials. This was to be expected because short-term complete detraining does not change anthropometric measures. Forced detraining studies from 2 weeks in endurance athletes[27] to 8 weeks in strength trained individuals[6] have shown no differences in body mass or body fat in trained athletes.

What is already known on this topic

- Detraining leads to reduced performance and increased risk of injury.
- Reduction in speed, power and aerobic capacity will hinder competitive tennis players in achieving their optimum potential.

What this study adds

- After as little as 5 weeks of unsupervised training in competitive tennis, players shows a decrease in speed, power and aerobic capacity.
- Coaches and trainers need to be aware of the likelihood of detraining when athletes are not supervised and put appropriate provisions in place to avoid this detraining effect

No significant changes in ROM at the shoulder were observed in this study (table 2). No differences were seen in the pre and post measures of hamstring, quadriceps, hip ROM as well as measures on the sit and reach test. Sit and reach flexibility is unaffected by 4 weeks of detraining in children, yet after 8 weeks, significantly impaired flexibility has been found.[28]

After obtaining these results we performed a retrospective questionnaire of the participants to ascertain why some of the important performance variables showed a significant decrease in results, similar to detraining studies.

Although tennis is an individual sport the group means for the self-report questionnaire help explain some of the obvious decreases in physiological variables seen during this study. On the self-reported questionnaire, the athletes responded that they completed only 32.5 (4.19)% of the assigned workouts during the break. They averaged hitting tennis balls approximately 10 (2.11) h/week and 3.5 (1.60) h/week in the weight room. They also averaged 1.75 (1.40) h/week on speed and agility training. Apart from the reduced volume, the players also responded that the intensity of training was reduced as well. They reported a drop of approximately 30% in intensity from their typical on-campus training (69.4 (4.12)%). Even though all players did not train with as much volume or intensity during the break period, it was not necessarily reflected in their subjective observations of whether they were in better or worse physical shape or whether or not they felt that their ball-striking and tennis skills had suffered.

CONCLUSIONS

This is the first study looking at the performance changes during a 5 week period of off-campus unsupervised, yet structured training between the autumn and spring semesters in elite level male tennis athletes.

The results of this study highlight the need for coaches and trainers to analyse their players' pre- and post-break physiological variables to ensure that the players do not intentionally (or unintentionally) detrain during this important period. More research is needed in this area, especially to see how these results might change over the course of a competitive break from the home facility (ie, 6 week overseas tour for tournaments). Although this study found significance in many variables, a larger sample in future studies might find greater significance and provide increased support for these recommendations.

It is plausible that, at this level, increasing awareness of the decrements that are potentially suffered as a result of poor compliance to prescribed workouts could enhance the conformity of athletes to training regimens. Such measures could come in the form of weekly calls home to encourage athletes to continue training or having post-break performance standards that must be met. Written logs of training during the break periods might also offer a potential solution. It is also important that the characteristics that show the quickest decreases in performance become a major focus of the off-campus program. These would include extra emphasis on training for aerobic capacity, speed and the ability to maintain power output.

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COMMENTARY 1

Detraining effects have never been properly investigated for tennis players. This research shows that after a break of a couple of weeks, significant detraining effects occur, even though players were instructed to do physical 'homework'. This is useful information for coaches, because after the break players return less fit and time is wasted regaining the pre-break level of fitness.

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COMMENTARY 2

This article provides a new insight into the physical and physiological changes of break periods during a US Collegiate tennis season. Coaches and sports scientists must use this kind of study in order to best prepare tennis players. Further research is needed in relation to 'competitive breaks' throughout the season.

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