



Interval Return to Play Programs for the Tennis Athlete

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Abstract

Purpose of Review General guidelines exist for return to sport after injury. The goal of these guidelines is to outline phases of recovery that will minimize the risk of reinjury and promote an optimal return to function for the athlete. This paper analyzes the current research pertaining to interval return to play programs with a special focus on the tennis athlete. The authors examine the different components of an interval tennis program and work to develop what they feel are the necessary elements of the optimal return to sport guidelines for tennis athletes. These criteria are based on the available literature, research, and preliminary data collection as well as the personal experiences and clinical observations of the authors.

Recent Findings Interval sports programs are typically designed to guide the athlete back to competition after an injury. The current research reveals the obstacles present in implementing an appropriate interval sports program including a lack of consensus on which criteria is actually necessary and relevant. Limited research is present for interval tennis programs.

Summary Return to sport competition and sports science is continuously evolving. The authors highlight the necessary components in rehabilitation and performance principles for establishing a comprehensive interval tennis program. In addition, the role of technology in sports rehabilitation is assessed as it pertains to return to play. The authors proposed that interval sports program can help guide and direct future clinicians in their rehabilitation of the tennis athlete.

Keywords Tennis · Rehabilitation · Return to play · Tennis injuries · Interval tennis program · Sports medicine rehabilitation

Introduction

Tennis is one of the few sports that can be played throughout the lifespan. Although athletically demanding at its highest

level of competition, players of all skill sets can enjoy the game for many years. At every skill level, epidemiologic studies have demonstrated that the most common injuries remain the same. Injuries of any kind will interrupt practice, training, and competition. Most tournament withdrawals occur because of injuries. It is for this reason that an interval return to play program is a necessity for the tennis athlete of every level recovering from injury.

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Tennis Research

Longitudinal studies in the tennis world have shown that acute tennis injuries tend to occur in the lower extremities. In contrast, chronic injuries typically occur in the upper extremities and trunk and tend to be overuse in nature [1•]. Although these studies provide some insight into the types of tennis injuries sustained, actual incidences are difficult to directly compare due to the lack of homogeneity in denominators such as hours of play and differences in game, set, and match exposures [1•]. The purpose of this article is to review current literature on interval return to play tennis programs and discuss the obstacles in developing optimal guidelines.

In general, research in the overhead athletes comes from a wide spectrum of sports including tennis, baseball, volleyball, and javelin. Despite these options, a review of return to play in the literature has yielded limited research for the sport of tennis. The vast majority of research looking at the overhead athlete is from the sport of baseball and is predominantly related to pitch count, pitching biomechanics, and return to play after UCL reconstruction. In view of this, there remains very little consensus on return to play criteria in most sports.

One of the few articles in the past 20 years to bridge the gap from rehabilitation to performance utilizing return to play criteria was published by Reinhold [2•]. This work is largely responsible for developing the concept of an interval sports program (ISP). The primary goal of an interval sports program is to ensure an athlete returns in a manner that optimizes performance and minimizes risk of injury. A key component of any ISP is that includes sports-specific simulation [2•]. It is a systematic approach to guide an athlete through rehabilitation and into sport-specific activities. As a general practice, athletes are allowed to return to play when they demonstrate symmetric range of motion and strength and perform sport-specific activities without pain or limitations. For this reason, an ISP must take into consideration the role of the kinetic chain, the gradual progression of exercise volume, an appropriate warm-up and recovery, and the importance of optimal mechanics within the sports-specific training.

While the research by Reinhold et al. largely focuses on an interval sports program for baseball pitchers who have sustained an upper extremity injury, it does touch on tennis as it relates to the serve and groundstrokes. Specifically, Reinhold outlines a systematic approach slowly increasing tennis-specific strokes beginning with light practice and culminating in match play. However, many relevant factors were not addressed. Primarily, the research did not consider the type of upper extremity injury nor did it take into account the playing surface the individual would be returning to. Additionally, there was no account of an individual's level of play, frequency of play, stroke mechanics, or service volume. Undoubtedly, these factors will play an important role in developing a return to play program and begin to hint at the many obstacles involved in this undertaking.

One study focusing on tennis was reported by Hartwell et al. They researched the causes of retirement from the US Tennis Association (USTA) Pro Circuit tournaments in 2013 [3]. This retrospective study assessed the volume of incidences of injury and illness that resulted in withdrawal from the tournament. The incidences were recorded per 1000 match exposures in both the women's and men's singles draws. The findings were significant in that injury differences were found between genders. The study concluded that women were more likely to experience an injury when playing on clay surfaces and were more susceptible to injuries in the first half of the season. However, the injury rates for men peaked during the

months that players could qualify for the Grand Slam competitions. Perhaps gender differences and seasonal timing are two more factors that need to be considered in developing return to play criteria.

Other studies have examined specific aspects on volume-based training in tennis players. Meyer et al. studied the volume of tennis serves in the elite population and then used this data as a foundation to create an interval training program. This study determined that the professional male players served 63 more serves per match compared to their junior male counterparts [4••]. Professional female players served 10 more serves/match than their junior female counterparts. Additionally, male players hit an average of 2 more serves per set than female players, and professional players hit 4 more serves/set than junior players. The article states that the elite tennis player averages around 40 serves per set at a ratio of 3 first serves to every 1-s serve. This research implies that service volume loads should be estimated in advance in preparation for return to play. Nevertheless, the article is limited in that it only looks at the elite tennis player and does not account for serves that were hit in practice. As a result, there is no definitive number of serves hit through an entire competitive season.

Presently healthcare practitioners are determining a tennis player's return to play based on observation, clinical experience, and a small amount of available research. Many obstacles exist in creating these guidelines from its general lack of definition to the specific testing that should be used. The literature has demonstrated that the only existing consensus is that the athlete must attain certain criteria before engaging in sport-specific skill training. These criteria include full pain-free range of motion (ROM), no apprehension with movement, adequate dynamic stabilization, and optimal strength and muscular endurance. These tests help the practitioner determine the presence of body impairments that may limit the athlete's success and performance in both rehabilitation and sport. However, in order to fully appreciate the value of these tests, it is best to have an understanding of the demands of tennis as well as an athlete's pre-injury performance level. The test results are just empty numbers without some relevant data to which they can be compared.

The optimal return to play program for the tennis athlete invokes more questions than answers. Does the type of injury whether upper extremity vs lower extremity or non-operative vs post-operative matter? Should there be the same battery of tests for all injuries whether related to soft tissue, bone, or tendon? The rehabilitation and performance injury principles will generally be consistent, but what about the tennis-specific characteristics of the athlete? Should the return to play program take into account singles vs doubles player, serve and volley vs all court game, groundstroke stance (closed, semi-open, open), and/or the need to play on various tennis surfaces.

Return to Play for Tennis

Physiological healing and time are not the only factors that will determine when an athlete can return to tennis. As an athlete recovers from injury, they must relearn how to move and function without causing further damage to the injured body part. For this reason, a return to tennis program must progress sequentially through the stages of recovery allowing an athlete to adapt to increasing amounts of stress and volume. This, in turn, will improve the player's ability to perform as well as their confidence in those capabilities increases.

The authors of this article describe their own values when administering a return to tennis program. The establishment of these guidelines is based on the clinicians' clinical and medical experience in sports medicine as it relates specifically to tennis, research, and technology testing. Our Hospital for Special Surgery (HSS) interval tennis program (ITP) approach requires the athlete to successfully complete a criteria-based rehabilitation program prior to initiating any return to play. It is a multidisciplinary criteria approach that is progressive and sequential, based on exam, interventions, and reassessments. The program is broken into phases and is advanced when the athlete demonstrates the appropriate criteria in each phase. Subsequently, a gradual increase in load and volume is created for the recovering body part.

After successfully completing a criteria-based rehabilitation program, the authors have developed the HSS Return to play for the tennis athlete. This interval tennis program (ITP) has been based on clinical and research observations and preliminary data collection. The components include ROM of the recovering injured area as well as the rest of the kinetic chain, muscle flexibility length tests, strength testing via the Microfet (hand-held dynamometer) and force frame system, grip strength, movement assessment via motion capture, proprioception, fatigue protocol testing, and power testing.

For upper extremity injuries, a priority of the interval tennis program is to ensure the athlete has the necessary ROM to compete. When evaluating serving, we are always looking for whether the individual has the optimal total ROM in order to get into the serve position and control its deceleration. Overhead athletes commonly exhibit an excessive amount of shoulder external rotation while being limited in internal rotation when measured at 90° of abduction. This physiologic adaptation to the throwing shoulder occurs in those that play baseball, softball, and tennis [5, 6••]. Total range of motion (TROM) refers to the sum of glenohumeral (GH) external rotation and GH internal rotation measured at 90° of abduction. The TROM is expected to fall between 160 and 210° in the overhead athlete. Side-to-side differences of 10–15° are considered normal when examining GH external rotation and GH internal rotation individually; however, the TROM has consistently been found to be within 5° on bilateral comparison. Wilk has demonstrated that when TROM deficits are

≥ 5°, there is an associated 2.5 and 2.6 times increased risk for shoulder and elbow injury, respectively [6••, 7]. Wilk also demonstrated that pitchers whose TROM was limited to 5 degrees or more than the uninvolved side exhibited 2.5 times greater risk of sustaining a shoulder injury [6••, 7–9].

The literature has demonstrated that acute injuries tend to occur in the lower extremities, while chronic overuse injuries more often affect the upper extremities and trunk. Epidemiological studies report that a range of 39–65% of injuries occur in the lower extremity, while 24–46% occur in the upper extremity, and 8–22% occur in the head/trunk [1, 10–12]. For this reason, assessment of thoracic spine rotation and extension is included in the screening. The thoracic spine mobility plays a key role in the mechanics of the kinetic chain. Similarly, a lower extremity assessment needs to show appropriate joint mobility, muscle flexibility, conditioning, strengthening, and proximal control in order to handle the substantial forces involved in producing each stroke while minimizing risk of injury.

Modern tennis is characterized by relentless speed and power. As such, it is important to stress the role of the kinetic chain as it relates to each body part. The body absorbs large forces during the loading phase of any groundstroke followed by explosive concentric contractions of these same muscles. The game demands incessant loading and unloading of the dominant side particularly in the open stance forehand. Furthermore, the energy transfer involved in the service motion is the epitome of kinetic motion [13••, 14]. Studies have shown that 54% of power is generated from the legs and up to 21% is generated from the shoulder [9, 11]. If the knees are not bent more than 10 degrees, it places a 23% greater load on the shoulder and a 27% greater load on the elbow [9, 11]. This sequencing emphasizes the importance of a comprehensive evaluation of the entire kinetic chain.

Furthermore, tennis players, like many overhead athletes, often exhibit sport-specific adaptations leading to a relative decrease in the strength of the external rotators and thus a muscular imbalance in the rotator cuff. Studies examining side to side differences as well as muscle imbalances have been conducted to look at isokinetic, isometric, and eccentric strength in both healthy and injured athletes. In general, a healthy shoulder will display an isokinetic ER/IR ratio of 66% or an isometric ER/IR ratio of 75% while displaying 10% more overall rotator cuff strength of the dominant side when compared to the non-dominant side. Using this data, we can identify individual body parts that may be at risk for injury.

A key component of any interval sports program is testing an athlete's ability to generate force and produce strength. As such, a vital part of these tests is ensuring standardization and reliability. The golden standard in strength measurement is the use of isokinetic devices; however, these procedures are rather expensive, and not applicable in training areas or on the

courts. HSS utilizes the Microfet and Force Frame system. The Microfet, hand-held dynamometry (HHD) demonstrates greater sensitivity and intra-/inter-examiner reliability than manual muscle testing in identifying strength deficits of the whole kinetic chain. The Force Frame system has demonstrated accurate and reproducible isometric strength testing throughout all joints of the body.

Power output is another relevant area for tennis players. Medicine ball tests, particularly overhead throws, are the most valid and sport-specific power testing for the upper extremity. Medicine ball toss and rotation throws mimic tennis groundstrokes and involve the entire kinetic chain. In the past, vertical jump testing has been used to test lower body power. These results, however, have not shown a significant correlation with improved tennis performance. Nevertheless, current trends in sports medicine are highlighting the importance of the reactive strength index (RSI) [15, 16, 17, 18•, 19, 20•, 21] which is calculated by dividing jump height with ground contact time when performing the depth jump (DJ) [15, 22]. It is a measure of explosive power, and it can reveal a lack of power and amortization in end stage injury recovery.

It is important to note that when it comes to return to play, most benchmarks have been created for lower extremity injuries. The benchmarks used to determine lower limb strength and strength asymmetries have primarily been isometric tests. The research has shown that an injured limb should perform at 90% or greater of the non-injured limb before return to sport is considered. This measurement is indicated by a minimum score of 90% on the limb symmetry index (LSI). To date there are no upper extremity isometric tests utilized as objective markers. A recent study by Ashworth et al. evaluated the reliability of their own upper body isometric test. This test (termed ASH) is a long lever isometric test that replicates the shoulder movement in its functional role, testing both shoulders in prone in the I, Y, and T positions [23]. A force platform was utilized to measure force production. The study found that this ASH test was reliable in the three shoulder positions and able to quantify force production from the shoulder girdle [23].

The study presents an interesting alternative to objective testing of the upper extremity. However, a few limitations must be acknowledged. Although the ASH test demonstrated excellent reliability in the 3 shoulder positions, reliability does not equate to sensitivity. The norms need to be established in order to detect real change. Also, a standing test position could be more relevant and sports specific even if it offers greater test-retest variability. Clinically, the ASH test is ideal in that it is portable and allows for on-field testing. The ASH would be best when complemented with a corresponding comprehensive testing program.

ACL injuries must be a consideration in all high-level sports. Research regarding ACL injuries and return to play have shown a fourfold or more risk of reinjury within 2 years [24, 25]. The high reinjury risks are attributed to faulty biomechanics, muscle weakness, non-optimal movement strategies, and muscle fatigue. Poor endurance has been shown to lead to improper movement patterns and poor mechanics that inherently increase an individual's injury risk. In a study by Brechbuhl, VO_2 was measured as a physiologic response in both the 20-m multistage shuffle test (MSST) and their own Test to Exhaustion Specific to Tennis (TEST). The TEST consisted of the individual hitting balls at a constant velocity, which was dictated by a ball machine. Consequentially, this TEST actually reenacts some of the demands of tennis unlike many other options in the field. The study concluded that VO_2 values at submaximal and maximal load attained during TEST and MSST were both moderate predictors of a player's competitive ranking [26]. As a result, the importance of implementing an endurance component in a return to play protocol must be considered [27].

Interval Tennis Program

The authors have created a comprehensive interval tennis program (ITP) based on clinical observations and preliminary data collection combined with their own tennis experience and performance philosophies. Our belief is that a return to tennis program should involve a systematic and sequential

Table 1 Warm-up exercises

Body part	Examples
Upper extremity	Mobility/stretching: Posterior cuff if applicable, periscapular region, forearm, wrist flexors/extensors Arm swings, thread the needle Band rows, rotation, W's exercises
Trunk	Mobility of all planes of movement Thoracic extension via foam roller, bench Thoracic rotation via side lying, half kneel or squat
Lower extremity	Light jog around the court Dynamic flexibility: hurdle knees, bounding, leg swings Movement: side shuffles, butt kicks, cross overs, high knees

Table 2 HSS Interval Tennis Program (ITP)

Week	Mon/Wed/Fri	ITP considerations
1	<ul style="list-style-type: none"> • Warm-up 5-10 min “mini tennis” at service line • (M) 5–10 FH/GS 5–10-min rest • (W) 20–15 FH/GS BH/GS 10-min rest • (F) 25–20 FH/GS BH/GS 10-min rest 	<ul style="list-style-type: none"> • Weeks 1–3 avoid hitting with open stance for all groundstrokes for upper extremity injuries and 4–6 weeks for lower extremity injuries
2	<ul style="list-style-type: none"> • (M) 25–30 FH, 20–25 BH; 10-min rest • (W) 25–30 FH, 20–25 BH; 10-min rest • (F) 30–35 FH, 25–30 BH; 10-min rest 	<ul style="list-style-type: none"> • Weeks 1–3 avoid hitting with open stance for all groundstrokes for upper extremity injuries and 4–6 weeks for lower extremity injuries
3	<ul style="list-style-type: none"> • (M) 35–40 FH 30–35 BH 10–20 shadow SR • (W) 35–45 FH 35–45 BH 10–20 shadow SR • (F) 15–25 SR Easy (<50% force), 10-min rest • 40–50 FH 40–50 BH 15–20 FHV 15–20 BHV 	<ul style="list-style-type: none"> • Weeks 1–3 avoid hitting with open stance for all groundstrokes for upper extremity injuries and 4–6 weeks for lower extremity injuries • Volleys no fast velocity shots. Do not have your partner drill it at you
4	<ul style="list-style-type: none"> • Continue increase in groundstrokes by 10–15 weekly • 20–30 SR, ** Serves at 50% First Serve** • 15–20 FhV 10–15 BHV 30–35 SR 20–25, 10–15 SwV; 10-min rest ×2 	<ul style="list-style-type: none"> • Initiate advanced strokes, i.e., swinging volleys and slices if applicable to player’s skill level. Do not introduce a stroke player did not possess prior to injury
5	<ul style="list-style-type: none"> • Continue increase in groundstrokes by 10–15 weekly • 30–40 SR (1st serve 75%, 10–20: 2nd serve 50%); 10-min rest • Continue to increase volleys by 10–15 weekly • Initiate 5–10 OH (easy < 50% effort) 	
6	<ul style="list-style-type: none"> • Continue increase in groundstrokes by 10–15 weekly • 40–45 (1st serve 85%, 20–30: 2nd serve 50%); 10–20 OH • Practice all strokes (if applicable to skill level) without apprehension • Play 4 games 	<p>Tips >5wks:</p> <ul style="list-style-type: none"> • Hit groundstrokes in semi-closed and open stance • Return to normal spin depending on individual’s shot • Make sure to follow-through with strokes (no short cuts) • Initiate high and low shots, high balls, all shots hitting crosscourt and down centerline
7	<ul style="list-style-type: none"> • 40–45: 1st serve 90%, 20: 2nd serve 75%); 25–30 OH • Practice applicable strokes to skill level without apprehension • Play simulated 1 set match following rules taking rest breaks with every 3rd game 	<ul style="list-style-type: none"> • Return to match play if no pain experienced in prior weeks (1st serve 90–95%, 2nd serve 75–80%) • Slowly work up towards 100% in each serve. Continue to practice all strokes (applicable to skill level)
8	<ul style="list-style-type: none"> • 1st and 2nd serve 100% effort without apprehension • M/W: Play simulated 1 set match following rules taking rest breaks with every 3rd game • F: Play simulated 2 set match following rules taking rest breaks with every 3rd game 	<p>Modifications for ITP:</p> <ul style="list-style-type: none"> • Non-competitive players/amateurs (plays < 10 year) advance strokes not applicable, ITP completed in 4–5 weeks • Competitive recreational players (USTA level >3.0/juniors/collegiate and professional proceed with full ITP

FH forehand, *BH* backhand, *FHV/BHV* fore/back hand volley, *SwV* swinging volley, *OH* overhead, *SR* serve

progression with the goal of evaluating an athlete’s readiness to return to tennis. The athlete undergoes the ITP when they pass a variety of tests and proceed through the stages of sport readiness. The different levels include sequential improvement in control of structural osteokinematics and arthrokinematics, functional movements, skill development, “competition integration” (refer to Table 2), and ultimate competition.

In outlining our ITP, the rehabilitation and performance process includes the control of both osteokinematics and arthrokinematics. This control is necessary for structural and functional movement. Our assessment includes a passive motion exam of the local level joint. Functional movement control translates to the dynamic assessment of the injured area. Skill development reflects the athlete’s kinetic linking ability

through multiplanar movements. In this phase, an elite player will resume his/her work with a coach or instructor in addition to the rehab staff. “Competition integration” specifically refers to one’s ability to control workload and threshold recognition [28]. This represents an athlete’s ability to perform under a controlled workload and ultimately determines the return to full competition. At this level, we incorporate an awareness of volume and load as it relates to the specifics of the game. This can include numbers of serves, the types of serves hit, number of groundstrokes, stances of groundstrokes, and even the number of points/games/sets played. The athlete must successfully complete these markers in order to be cleared for match play, the ultimate, uncontrolled environment. The ITP markers are progressed sequentially when no pain or complications are present. Aside from administering these physical tests, some

attention must also be given to the mental component of sport. Suffering an injury will commonly affect an athlete's mental state wherein they will experience anxiety, apprehension, and fear. Part of the ITP will be to evaluate the psychological readiness of an athlete. There are many outcome measures that allow us to do this. One of the most common is the TAMPA scale of kinesiophobia which has been frequently utilized by the authors.

To initiate the ITP, the athlete must include a comprehensive conditioning of the entire body including a proper warm-up and recovery regimen. This warm-up should include full-body exercises as well as movements specific to the injured body part (refer to Table 1 for specific warm-up exercises for different areas). Moreover, the athlete must have a minimal cardiopulmonary tolerance of 45 min–1 h of continuous aerobic activity.

HSS Interval Tennis Program (Table 2)

The general tips when initiating the ITP are the following:

- Prior to first week, play “mini” tennis for 15–30 min, 2–3× week.
- Hit groundstrokes in neutral stance—aiming for the center backcourt.
- Have partner hit the ball at waist level (no high balls). If ball is high, do not swing!
- Minimize spin with shots (NO extreme spin, i.e., no wind-shield wiper, NO WIND UP).
- Make sure to follow-through with strokes (no short cuts), i.e., NO large backswing. Basic low to high strokes.
- Continue to work with coach/instructor, and ensure proper footwork.
- Initiate with low compression balls, and gradually progress to regular tennis balls.

This ITP looks to gradually build an athlete's activity volume with a focus on tennis and managing the tennis load. “The aim of load management is to optimally configure training, competition and other load to maximize adaptation and performance with a minimal risk of injury. Load management therefore comprises the appropriate prescription, monitoring and adjustment of external and internal loads.” [12, 29] The athlete's tennis volume is assessed over a course of 5 to 8 weeks dependent on the skill level of the athlete.

Conclusion

More objective studies need to be conducted in regard to tennis and return to play criteria. Although many overhead sports share similarities, healthcare practitioners need to be careful

when applying interval guidelines to different sport injuries. A successful return to tennis program will incorporate the athlete's history and physical examination and will, ideally, provide insight into the pathology creating an individual's dysfunction. The HSS ITP provides the tennis athlete a systematic training program that values load management and includes both controlled and uncontrolled environments in the successful return to competition.

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Compliance with Ethical Standards

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