

[Athletic Training]



Data-Based Interval Hitting Program for Female College Volleyball Players

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Context: Interval sports programs are a critical rehabilitation element when preparing the injured athlete for a return to preinjury activities. There is currently no published interval hitting program to guide a return to unrestricted play for the volleyball athlete. Therefore, data-based, position-specific overhead hitting programs that control for intensity, time, and number of ball strikes were developed for female college volleyball players.

Evidence Acquisition: Records from a single Division I varsity women's volleyball team were examined for all matches during 7 consecutive years of team play. Data were collected for number of hitting and service attempts per game for each position and the number of games per match.

Results: Per game, middle hitters averaged 4.51 attacks and 2.77 service attempts; right-side hitters, 3.58 attacks and 1.26 service attempts; outside hitters, 6.37 attacks and 3.44 service attempts; and setters and defensive specialists, 0.17 attacks and 1.78 service attempts.

Conclusion: The interval hitting program can provide rehabilitation specialists with a data-based approach that may facilitate a return to play and minimize the risk of reinjury for volleyball athletes.

Keywords: return to play; rehabilitation; shoulder joint

Volleyball is among the most popular sports in the world, with the Federation Internationale de Volley-Ball reporting more than 500 million participants worldwide.⁷ In the United States alone, there are more than 400 000 participants at the high school level and an additional 13 000 competitive collegiate volleyball players.^{28,29} As a sport played within a broad range of skill levels and ages and as combined with many sport-specific skills, volleyball results in a variety of injuries.

Epidemiological studies have described the incidence and types of injuries common among volleyball participants. Data collected by the National Collegiate Athletic Association's injury-surveillance system over a 16-year period (1988-1989 through 2003-2004) indicated that among female participants, risk of volleyball injury (defined as at least 1 missed day of practice or competition) was slightly higher during a game than during practice (4.58 and 4.10 per 1000 athlete exposures, respectively).¹ Shoulder injuries are common in both settings. During games, shoulder muscle/tendon strains were the third-most-common injury (5.2%) reported by the injury-surveillance

system.¹ Shoulder subluxation and tendonitis accounted for an additional 4.5% of game injuries.¹ Combined, shoulder muscle/tendon strains, tendonitis, and subluxation account for 11.8% of injuries sustained during practice.¹ Similarly, Verhagen et al³⁶ reported that 9% of all injuries during an indoor Dutch volleyball season occurred at the shoulder, whereas Bahr and Reeser⁸ reported 10% of all overuse injuries reported during part of a professional beach volleyball season occurred at the shoulder. The consistency among these studies places the shoulder as one of the top 3 volleyball related-injury risks.³¹

The arm motions necessary to perform a volleyball serve or spike are similar to those of tennis and baseball: there are extreme ranges of motion enacted and high forces generated, resulting in microtraumatic stresses placed on the shoulder. Changes in hitting mechanics,^{9,18} muscle weakness or imbalance,⁵ and changes in range of motion^{18,38} may lead to tissue breakdown or injury.⁴³ Injuries most commonly seen in volleyball include rotator cuff and biceps tendonitis, impingement, glenohumeral instability, labral tears,^{18,22,25,37}

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and suprascapular neuropathy.^{13,16,27,35} Shoulder rehabilitation programs have traditionally included a gradual restoration of range of motion (primarily, internal rotation), rotator cuff and scapular strengthening through closed-chain concentric and eccentric exercises, muscular endurance retraining, dynamic stabilization, neuromuscular control, and plyometrics.¹¹ Successful completion of these exercises is necessary before the athlete may progress to a more advanced phase of the rehabilitation program. During this final step of the rehabilitation process, the athlete must be exposed to stresses that imitate practice and game conditions to minimize the risk of reinjury.

Rehabilitation programs used for the injured volleyball athlete should also include a structured interval hitting program (IHP).⁶ The purpose of an IHP is to return an athlete to preinjury activity levels through a controlled stepwise progression that systematically exposes the tissues to sport-specific stresses and thus minimizes the risk of reinjury. Rehabilitation activities can approximate, but do not completely re-create, joint forces and loads that the athlete will experience during sports participation. For example, the distance, intensity, and number of throws for a baseball player may be reproduced only by the act of throwing a baseball. Consequently, the literature describes a variety of interval sports programs, including baseball,^{3,4,32} softball,^{5,17} golf,³² and tennis.³² Many are subjective and based merely on how quickly the authors believe an athlete should return to play. In contrast, Axe and colleagues³⁻⁵ have developed data-based interval throwing programs for baseball^{3,4} and softball⁵ players based on game data, game rules, and type of injury. Their interval programs provide athletes with an objective sports progression that may be used within a comprehensive rehabilitation program for injured athletes and to augment off-season workouts. Despite widespread participation and significant shoulder injury rates among volleyball participants, we found no published data-based IHPs for volleyball.

Therefore, the purpose of this study was to develop data-based IHPs for collegiate female volleyball players at all positions. These IHPs and their progression are based on the game data collected, the rules of the game, and the type of injury sustained.

METHOD

Data Acquisition

With institutional review board approval, data from statistics accumulated during a Division I women's college volleyball team over 7 seasons were collected: the number of serving and attack attempts per game for each position and the number of games per match. The hitting programs were conducted for each position (outside, right, and middle attackers; setter) from these data and court dimensions, as outlined by National Collegiate Athletic Association's volleyball rules (see Figure 1).²

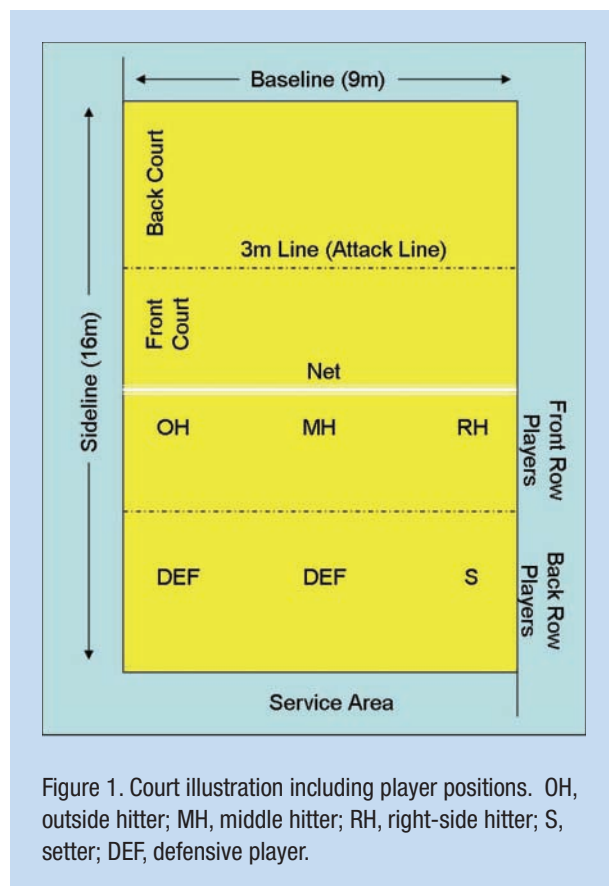


Figure 1. Court illustration including player positions. OH, outside hitter; MH, middle hitter; RH, right-side hitter; S, setter; DEF, defensive player.

Data Management

The IHPs were constructed with consideration for the position played, the data collected, the most frequently occurring volleyball injuries, and a general knowledge of tissue-healing times and properties. Separate programs were developed for each player position, including the setter and the outside, middle, and right attackers. Different programs were developed for each position secondary to the differences in game demands, including the volume of service and attack attempts.

Service attempts are performed to initiate each point. This skill requires the player stand behind her end line and toss the ball into the air before striking it so that the ball crosses the net into the opponent's court. Despite multiple variations, most service attempts require an overhead motion while the player maintains contact with the ground. Advanced players may, however, perform a jump serve. In this variation of a service attempt, the ball is tossed higher and into the court, giving the player an opportunity to jump as they strike the ball. This can result in a more powerful, downwardly directed ball delivery. Attack attempts, also referred to as *bites*, *spikes*, and *overhead attacks*, are performed to forcefully send the ball across the net into the opponent's court. This skill routinely involves a player jumping and performing an overhead arm motion, making contact when the ball is above the net. The difference from the service attempt

¹¹References 9, 10, 19-21, 23, 24, 26, 30, 32, 39, 42, 43

is that, with an attack, the player is attempting to hit a ball that is already in play and has been contacted by another player. Arm motion in the service and attack attempt is categorized as an overhead motion, with similarities to the tennis service and baseball throwing motion. Relative to player positions, setters typically have the fewest attack attempts. The setter handles the ball after service reception (the second ball contact), with the responsibility of passing the ball for one of the hitters to attack. The hitters—outside, middle, and right side—are the players in the front row who assume the bulk of the attack responsibilities.

The ranges, instead of the means, were used to develop the hitting programs to accommodate game demand variability; thus, each program represents the maximum of activities a player will encounter at a given position. Workout volume was calculated at each step as the product of the number of hits \times intensity \times number of sets (when appropriate). The goal of the hitting program was to gradually increase the intensity (approximately 25% per step). An intensity of 80% was used in the calculation for service attempts.

Game placement serves are full-effort serves to a specific court area, and they are intended to mimic game situations. Thus, this skill is distinct from service attempts that address effort but have no directional component. Rest intervals between sets were based on game rules, with time intervals between sets during match play ranging from 3 to 10 minutes. The rest time between service attempts was not based on game rules. Time between serves during a match is dependent on the length of the ensuing point. Consequently, this rest interval is an estimation of the time between serves that a player may have during match play.

RESULTS

The average number of games per match for each position was 3.67 ± 0.15 , based on a best-of-5 format. Outside attackers averaged the most hitting attempts, with 6.37 per game, followed by middle and right attackers (4.51 and 3.58, respectively); setters averaged fewer than 2 attack attempts per game (Table 1). Setters attempted more serves than those of any other positional players, averaging 3.96 serves per game; outside and middle attackers followed, with 3.44 and 2.77 service attempts per game, respectively. Right attackers averaged fewer than 2 service attempts per game.

Program Design

The data led us to write 4 IHPs: separate programs for the 3 attacker positions and the setter (Tables 2-5). The programs are designed to take an athlete from no hitting to the hitting volume and intensity present in a game situation. Each program includes what is termed *full-court hits*, which were not included in calculating program intensity. Full-court hits are the volleyball equivalent of the long toss in baseball. With full-court hits, the athlete's goal is to lob the ball over the net with a three-quarter overhead swinging motion while maintaining a grounded position from the back row and

Table 1. Volleyball game data: Mean \pm SD.

Position	Attacks	Serves
Middle	4.51 \pm 2.02	2.77 \pm 1.40
Outside	6.37 \pm 2.61	3.44 \pm 0.67
Right side	3.58 \pm 1.37	1.26 \pm 1.40
Setter	1.45 \pm 0.73	3.96 \pm 1.01

stepping into the hit. Full-court hits were designed to increase muscular strength and endurance throughout the hitting progression. In addition to full-court hits, attack hits and serves compose each step of the hitting program.

The number of steps composing each program ranges from 6 to 10, with setters having the fewest and with outside hitters having the greatest. The variable number of steps in each hitting program reflects the volume of hitting for each position identified during data acquisition. Initial steps of each program include 50% effort serving and attack hits, along with the easy full-court hits. These early steps allow the athletes to build the baseline strength and endurance necessary for intensified activity. Hitting volume then slowly advances throughout the program by increasing repetitions, sets, or intensity. As the athlete approaches the later steps of the hitting program, game placement serving is added. It functions as preparation for return to full activity by increasing physical demands on the upper extremity and exposing the player to competitive activity. The final step of the IHP finds the athlete performing full effort attacks and serves at the maximum game demand for repetitions.

Program Progression

Soreness rules. The instructions and soreness rules (Table 6)⁴ guide the player through the IHP progression and are necessary to maximize program effectiveness. Healing rates are highly variable; thus, the soreness rules allow the athlete to modify progression according to symptoms and to individualize each program. Specifically, the soreness rules dictate when an athlete may progress to a higher step, remain at the same step, and drop down a step and how much rest time is indicated between hitting days. These collective qualities of the soreness rules minimize the possibility of oversteering healing tissue as the athlete prepares for return to play.

Injuries. We have developed an injury classification scheme to modify the return to play timeline: when to begin hitting, how many days of rest are necessary between hitting days, and how quickly the athlete may progress through the IHP (Table 7).⁴ Injuries to parts of the body outside of the hitting arm require minimal program modification, followed by injuries to

Table 2. Outside attacker hitting program.

Step 1	Step 2
20 warm-up hits (40%-50%)	20 warm-up hits (40%-50%)
8 attack hits (50%), 2 sets ^a	10 attack hits (50%), 2 sets ^a
10 easy full-court hits	4 serves (50%) ^b
	10 easy full-court hits
Step 3	Step 4
20 warm-up hits (50%)	20 warm-up hits (50%)
8 attack hits (50%), 3 sets ^a	10 attack hits (50%), 3 sets ^a
4 serves (50%), 2 sets ^b	4 serves (50%), 3 sets ^b
10 easy full-court hits	10 easy full-court hits
Step 5	Step 6
20 warm-up hits (50%-75%)	30 warm-up hits (50%-75%)
8 attack hits (75%), 3 sets ^a	9 attack hits (75%), 3 sets ^a
3 serves (75%), 3 sets ^b	3 serves (75%), 3 sets ^b
15 easy full-court hits	15 easy full-court hits
Step 7	Step 8
30 warm-up hits (50%-75%)	30 warm-up hits (50%-75%)
10 attack hits (75%), 4 sets ^a	8 attack hits (75-100%), 4 sets ^a
4 serves (75%), 3 sets ^b	5 serves (75%), 4 sets ^b
15 easy full-court hits	20 easy full-court hits
Step 9	Step 10
30 warm-up hits (50%-75%)	30 warm-up hits (50%-75%)
10 attack hits (75%-100%), 4 sets ^a	12 attack hits (75%-100%), 4 sets ^a
5 game placement serves, 4 sets ^b	5 game placement serves, 4 sets ^b
20 easy full-court hits	20 easy full-court hits

^aRest 45-60 seconds between hits, 6-8 minutes between sets.

^bRest 30 seconds between serves, 6 minutes between sets.

the hitting arm that do not involve the joint (ie, bruises). Injury to the elbow and/or shoulder of the hitting arm may range from mild (tendonitis) to severe (postoperative cases) and necessitate appropriate program modification. Commencement of a hitting program is a team decision, with the physician and the rehabilitation specialist consulting to determine patient

readiness. Despite no standardized guidelines for return to play after an upper extremity injury, we advocate that the athlete have full range of motion, no effusion or pain, good strength (80%-90% on bilateral comparison), and a satisfactory clinical exam before beginning sports activities. Initiation of the IHP is based on criteria of rehabilitation advancement that takes

Table 3. Setter hitting program.^a

Step 1	Step 2
20 warm-up hits (40%-50%)	20 warm-up hits (40%-50%)
3 attack hits (50%), 2 sets ^b	4 attack hits (50%), 3 sets ^b
5 serves (50%), 2 sets ^c	6 serves (50%), 2 sets ^c
10 easy full-court hits	10 easy full-court hits
Step 3	Step 4
20 warm-up hits (50%)	25 warm-up hits (50%)
4 attack hits (75%), 3 sets ^b	4 attack hits (75%), 4 sets ^b
6 serves (50%), 3 sets ^c	5 serves (75%), 3 sets ^c
10 easy full-court hits	15 easy full-court hits
Step 5	Step 6
25 warm-up hits (50%-75%)	30 warm-up hits (50%-75%)
4 attack hits (75%), 4 sets ^b	4 attack hits (75%-100%), 4 sets ^b
6 game placement serves, 3 sets ^c	6 game placement serves, 4 sets ^c
15 easy full-court hits	20 easy full-court hits

^aAverage increase per step, 26%.

^bRest 45 seconds between hits, 10 minutes between sets.

^cRest 30 seconds between serves, 6-8 minutes between sets.

tissue-healing time frames into consideration. Once hitting has begun, the athlete can progress as the injury classification and soreness rules allow.

DISCUSSION

No data-based IHPs developed for collegiate volleyball players have been published. The IHP being suggested is not intended to serve as a substitute for traditional rehabilitation programs, but it should be used to augment those treatments. Any rehabilitation program of an injured athlete must include a controlled environment for return to play, accommodating expeditious participation while minimizing the risks of reinjury.

Many of the shoulder injuries seen in volleyball players are similar to those found in other overhead sports.²⁶ Impingement, glenohumeral instability, undersurface rotator cuff tears, and glenoid labrum tears are common among all overhead athletes, whereas suprascapular neuropathy and bicipital tendonitis injury reports are much common among volleyball participants.^{9,13} Successful skill execution of the overhead serve and attack exposes the shoulder to tremendous forces and torques. High

muscle activity of the posterior rotator cuff during acceleration and energy dissipation during deceleration phases of the hitting motion,³³ combined with extremes of glenohumeral and scapular motions, contribute to the soft tissue adaptive changes seen in the dominant extremity: decreased shoulder internal rotation range of motion, decreased shoulder external rotation strength, increased shoulder depression, and increased anterior glenohumeral laxity.^{9,18,22,37,38} A successful rehabilitation program identifies all factors contributing to the injury process and prepares the athlete to withstand the stresses associated with sport participation.

Note that there were several limitations in the development of data-based IHPs for collegiate female volleyball players. Our study was limited by the playing personnel and coaching system from a single school over the period that data were collected. We should acknowledge that the attack and service attempts may range considerably for different schools, personnel, and coaching systems. For example, at the net, left-handed athletes who play as setters and right-side attackers have an advantage compared to their right-handed counterparts; consequently, attack attempts for left-handed players at those positions are

Table 4. Middle attacker program.^a

Step 1	Step 2
20 warm-up hits (40%-50%)	20 warm-up hits (40%-50%)
8 attack hits (50%), 2 sets ^b	10 attack hits (50%), 2 sets ^b
10 easy full-court hits	4 serves (50%) ^c
	10 easy full-court hits
Step 3	Step 4
20 warm-up hits (50%)	20 warm-up hits (50%)
9 attack hits (50%), 3 sets ^b	10 attack hits (50%), 3 sets ^b
4 serves (50%), 2 sets ^c	5 serves (50%), 3 sets ^c
10 easy full-court hits	10 easy full-court hits
Step 5	Step 6
20 warm-up hits (50%-75%)	30 warm-up hits (50%-75%)
8 attack hits (75%), 3 sets ^b	10 attack hits (75%), 3 sets
4 serves (75%), 3 sets ^c	4 serves (75%), 3 sets ^c
15 easy full-court hits	15 easy full-court hits
Step 7	Step 8
30 warm-up hits (50%-75%)	30 warm-up hits (50%-75%)
10 attack hits (75%), 4 sets ^b	8 attack hits (75%-100%), 4 sets ^b
4 serves (75%), 4 sets ^c	5 serves (75%), 4 sets ^c
15 easy full-court hits	20 easy full-court hits
Step 9	
30 warm-up hits (50%-75%)	
10 attack hits (75%-100%), 4 sets ^b	
6 game placement serves, 4 sets ^c	
20 easy full-court hits	

^aAverage increase per step, 21%.

^bRest 45-60 seconds between hits, 6-8 minutes between sets.

^cRest 30 seconds between serves, 6 minutes between sets.

typically higher than they are for right-hand-dominant players. Coaching philosophies and systems are highly variable in volleyball and can range from traditional front-row attacks to back-row attacks and combination plays. Service execution is also highly variable and includes the floater, topspin, and jump serves. Further individualization of the IHP beyond the soreness roles and injury classification system may be provided

by the rehabilitation specialist who possesses a more extensive background in volleyball; that is, he or she can take such variability into consideration. In addition, the IHPs were based on data obtained from female collegiate volleyball participants during competition. Caution must be taken when implementing these programs for men and for women who do not compete at the collegiate level. Although the proposed interval programs

Table 5. Right-side attacker program.^a

Step 1	Step 2
20 warm-up hits (40%-50%)	20 warm-up hits (40%-50%)
6 attack hits (50%), 2 sets ^b	6 attack hits (50%), 2 sets ^b
10 easy full-court hits	4 serves (50%), 2 sets ^c
	10 easy full-court hits
Step 3	Step 4
20 warm-up hits (50%)	20 warm-up hits (50%)
6 attack hits (50%), 3 sets ^b	6 attack hits (75%), 3 sets ^b
4 serves (50%), 3 sets ^c	4 serves (50%), 3 sets ^c
10 easy full-court hits	15 easy full-court hits
Step 5	Step 6
25 warm-up hits (50%-75%)	30 warm-up hits (50%-75%)
6 attack hits (75%), 3 sets ^b	6 attack hits (75%), 4 sets ^b
4 serves (75%), 3 sets ^c	4 game placement serves, 4 sets ^c
15 easy full-court hits	20 easy full-court hits
Step 7	
30 warm-up hits (50%-75%)	
7 attack hits (75%-100%), 4 sets ^b	
4 game placement serves, 4 sets ^c	
20 easy full-court hits	

^aAverage increase per step, 26%.

^bRest 45-60 seconds between hits, 6-8 minutes between sets.

^cRest 20 seconds between serves, 6 minutes between sets.

may serve as a reasonable progression to facilitate a return to volleyball for all participants, we advocate additional data-based interval programs for each sex and level of participation. Despite these limitations, the development of IHPs for collegiate female volleyball players is a valuable advancement that provides an objective, progressive return to sport that rehabilitation specialists may use when treating this population.

CONCLUSION

The goal was to develop data-based IHPs for collegiate-level female volleyball players in all positions. These programs should be used as functional progressions within rehabilitation programs for the injured volleyball player. Individualizing

the programs is encouraged and should be performed on the basis of input from the player and coaching staff. Clearance to initiate an IHP is a team decision, involving all members of the medical team. Criteria-based advancement throughout all phases of the rehabilitation program and attention to tissue-healing properties form the foundation for that decision-making process. With education from the supervising rehabilitation specialist regarding program design and progression, the athlete, coach, and athletic trainer may continue with the program after formal rehabilitation is completed. We believe that our proposed IHPs for the collegiate female volleyball player, along with their appropriate implementation, may facilitate return to play while minimizing the risk for reinjury.

Table 6. General and soreness rules.⁴

General rules	<ol style="list-style-type: none"> 1. Break a sweat. 2. Shoulder stretches. 3. Hitting program. 4. Rotator cuff strengthening. 5. Shoulder stretches. 6. Ice for 20 minutes.
Soreness rules	<ol style="list-style-type: none"> 1. If sore more than 1 hour after hitting or the next day, take 1 day off and repeat the most recent hitting program workout. 2. If sore during warm-up but soreness is gone within the first 15 hits, repeat the previous workout. If shoulder becomes sore during this workout, stop and take 2 days off. On return to hitting, drop down 1 step. 3. If sore during warm-up and soreness continues during the first 15 hits, stop hitting and take 2 days off. On return to hitting, drop down 1 step. 4. If no soreness, advance 1 step every hitting day.

Table 7. Injury classification.⁴

A. Non-hitting-arm injury
After medical clearance, begin with step 1 and advance 1 step daily, following soreness rules.
B. Hitting arm: bruise or bone involvement
After medical clearance, begin with step 1 and advance every other day, following soreness rules, to end of program.
C. Hitting arm: tendon/ligament/nerve injury (mild)
After medical clearance, begin with step 1. For the first week, hit every third day, following soreness rules. After the first 2 weeks, advance program as soreness rules allow, hitting every other day, to end of program.
D. Throwing arm: tendon/ligament/nerve injury (moderate, severe, postop)
After medical clearance, begin with step 1. For the first 2 weeks (days 1-14), hit every 3-4 days and do not advance beyond step 1. On days 15-28, begin hitting with step 2 every 2-3 days but do not advance beyond step 2. On days 29-42, use soreness rules to advance program, hitting every third day. If no soreness, hit the warm-up and easy full-court hits of the previous days workout on off days.

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