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CLINICAL COMMENTARY

RETURN TO HITTING: AN INTERVAL HITTING PROGRESSION AND OVERVIEW OF HITTING MECHANICS FOLLOWING INJURY

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ABSTRACT

Background and Purpose: Participation in baseball is prevalent across all age groups. Baseball injuries are common and can impact a player's ability to participate. An injury to any region can influence the player's ability to swing the bat. As a part of the athlete's rehabilitation, a sports-specific program should be implemented re-introducing the hitting cycle that addresses proper biomechanics as well as providing a progressive atmosphere to return to hitting. Although there are several return to throwing progression programs in the literature, to the author's knowledge no published hitting progression programs exist. Thus, the purpose of this clinical commentary is to propose a progressive return to hitting program that emphasizes proper mechanics for ballplayers who have sustained an injury.

Description of Topic: This return to hitting program describes in detail the phases of the baseball hitting cycle. Proper biomechanical information is provided on each phase that can be used to assist the clinician in injury prevention. This article gives the healthcare professional guidance for assessment for appropriate readiness for return to sport using impairment measures, patient-report measures, and physical performance measures. The purpose of this hitting progression is to provide a safe, gradual increase in hitting intensity by moving from a fixed position to soft toss and finally to increasing pitch velocity.

Discussion: This interval hitting program guides the clinician from when the patient is ready to begin hitting through a full return to sport. Use of appropriate hitting mechanics must be ensured during rehabilitation to avoid compensation. Similar to the return to throwing programs that exist, this interval hitting progression program can provide a framework to quantify progression and reduce the chance of re-injury from occurring during the return to sport phase of rehab.

Keywords: Baseball, hitting, injury progression

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INTRODUCTION

Baseball has gained popularity over the years and participation continues to increase. Estimates have shown that 4.8 million children between the ages of 4-15 years old participate in some form of competitive or recreational baseball.[1] This popularity does not stop at the youth level of play, rather it continues into higher levels as well. As many as 11.5 million athletes participate in the sport of baseball at the high school and club levels.[2] Compared to other high school sports, baseball and softball were ranked second in popularity during the 2012-2013 school year.[3] An estimated 27,262 athletes are involved in baseball amongst all divisions of collegiate play.[4] At the professional level, 750 athletes participate in Major League Baseball while approximately 2,100 participate in minor league baseball each year.[5]

As with any other sport, playing baseball can lead to injury. To ensure the athlete does not suffer another injury, the athlete should be slowly progressed back into sport. Interval sport programs are created to provide a progressive atmosphere in which the athlete can return to sport-related tasks in a safe manner.[6] Although several return to throwing progression programs exist in the literature, to the author's knowledge no current hitting progression program is available in the published literature. Experts in the past have postulated such a program; however, further commentary and detail needs to be addressed.[7] In addition to a progressive return to hitting program, an introduction of proper biomechanics related to the baseball swing that uses the entire kinetic chain must be addressed to reduce the onset of re-injury.

INJURIES IN BASEBALL

Between the years of 1994 to 2006, an estimated 1,596,000 children under the age of 18 were treated in United States emergency departments for baseball related injuries.[2] Injuries that occur in baseball can involve the upper extremity, lower extremity, back, head/neck and the trunk. For college participants, of the reported injuries 58% were of the upper extremity, 27% involved the lower extremity, 15% involved the trunk or back, and 7% the head or neck.[4] At the professional level, 47%-51% of injuries involved the upper extremity.[8,9] At the high school level, 1.49 injuries occur per 10,000 athletic exposures, with an estimated 64,229 injuries occurring annually in the United States.[10]

Risk of injury can also be influenced by position participation. Pitchers at the professional level, many of whom do not bat, missed more days of play related to upper extremity injuries, whereas catchers and positional players missed more days for lower extremity injuries.[9] Younger players may find themselves not only pitching, but also playing additional positions. Risk of injury at this young age is rising as participants play on more teams during a single year and throw more during practices and games.[11, 12] The frequency at which medial elbow pain occurs in adolescent baseball players can be found to be between 4 -49%.[13, 14]It is not atypical for a youth athlete to be called upon to play a position in the field, possibly pitch, and bat in a regular season of play. Due to the high axial trunk velocity that occurs during the baseball swing, injuries can occur at the lumbar spine and abdominal musculature as well. Ten percent of the injuries among Major League Baseball players occurred in the trunk, and of these, half occurred in the abdominal musculature.[8] Other literature has shown that out of the reported 69 cases of symptomatic lumbar disc herniation, 58% of these injuries at the professional level were related to hitting.[15] Even though throwing causes most injuries in the upper extremity, the high velocity produced by the shoulders during the baseball swing combined with repetition can cause injury. A syndrome known as batter's shoulder occurs due to continual exposure to the baseball swing producing posterior instability of the lead shoulder; but the incidence of this injury is comparatively low.[16, 17] Even though most baseball and softball injuries are not a direct result of hitting, there is not a segment in the body that does not play a significant role in the player's swing. Much of the clinicians thought process is using regional interdependence to restore proper throwing mechanics as well as a controlled return to throwing. What many clinicians forget is that those injured players will have to return to hitting as well.

To return injured athletes back to all aspects of baseball or softball, many will need attention paid to return to hitting. As part of their rehabilitation, an appropriate return to hitting progression must occur

Table 1. *Phases of Hitting. The below phases have been adapted from Fleisig et al*[18]

Phases of the Hitting Cycle	Description	
Preparatory Phase	Occurs as the hitter assumes the proper position in the batter's box. The actual swing has not started in this phase	
Stance Phase	From weight shifting onto the back leg to the stride foot lift-off	Loading Period
Stride Phase	From stride foot lift-off to stride foot contact	
Drive Phase	From stride-foot contact to maximal loading of the bat	
Bat Acceleration Phase	From maximal loading of the bat to ball contact	
Follow-Through Phase	From ball contact to completion of the baseball swing	

to ensure the athlete's safety regarding re-injury and further injury prevention. To gain a full appreciation of this progression, one must first understand the biomechanics that occur during the hitting cycle. Thus, the purpose of this clinical commentary is to propose a progressive return to hitting program that emphasizes proper mechanics for ballplayers who have sustained an injury.

OVERVIEW OF HITTING MECHANICS

The mechanics of hitting have been broken into several phases: the preparatory phase, stance phase, stride phase, drive phase, bat acceleration phase and follow through phase.[18] (Table 1) These combined phases produce the baseball swing, which assists in making contact with the baseball. This section will make reference to the baseball swing; however, these thoughts could translate into the swing used by a softball player as well. In order to understand the intricate nature of the hitting cycle, one must be a keen observer of each phase and how their successive order can play an influential role in producing the swing.

PREPARATORY PHASE

Prior to initiating the hitting cycle, the batter must assume a position that is optimal and individualized to meet the needs of their swing. There are many personalized differences in preference for the stance. The closed stance, where the hitter's front foot is positioned closer to home plate than the back leg, is typically used by hitters who have a tendency to open their hips at an earlier moment.[19] It is also often used for hitters who have difficulty attempting to swing at pitches placed further away from their body.[19] Limitations to using this type of stance include the inability of the hitter to produce full rotation of the hips and axial spine, especially when pitches are thrown closer to the body.[19] Another stance that is often used by batters is the open stance. This is where the front foot is placed further away from home plate than the back leg, which is often used by hitters who have a tendency to pull the ball or hit toward their field of preference.[19] Other authors have argued that the square stance provides the most optimal position, where the feet are shoulder width apart and the toes are pointed toward home plate, because it gives the batter the ability to hit pitches that are placed within any area located around home plate.[19] This stance also provides no compensatory movement or extra motion to rotate through the baseball swing making it more efficient.[19]

After the athlete has assumed this preparatory position, the initiation of the baseball swing can be further discussed in several stages. Each one of these stages is summarized in Table 1. Like any other high velocity movement, the art of hitting is considered a plyometric activity. A plyometric exercise is defined as a "...quick, powerful movement using a pre-stretch, or countermovement, that involves the stretch shortening cycle.[20, 21]The purpose of plyometric exercise is to increase the power of subsequent movements by using both the natural elastic components of muscle and tendon and the stretch reflex".[20] The loading period of the swing causes a countermovement which produces a quick eccen-

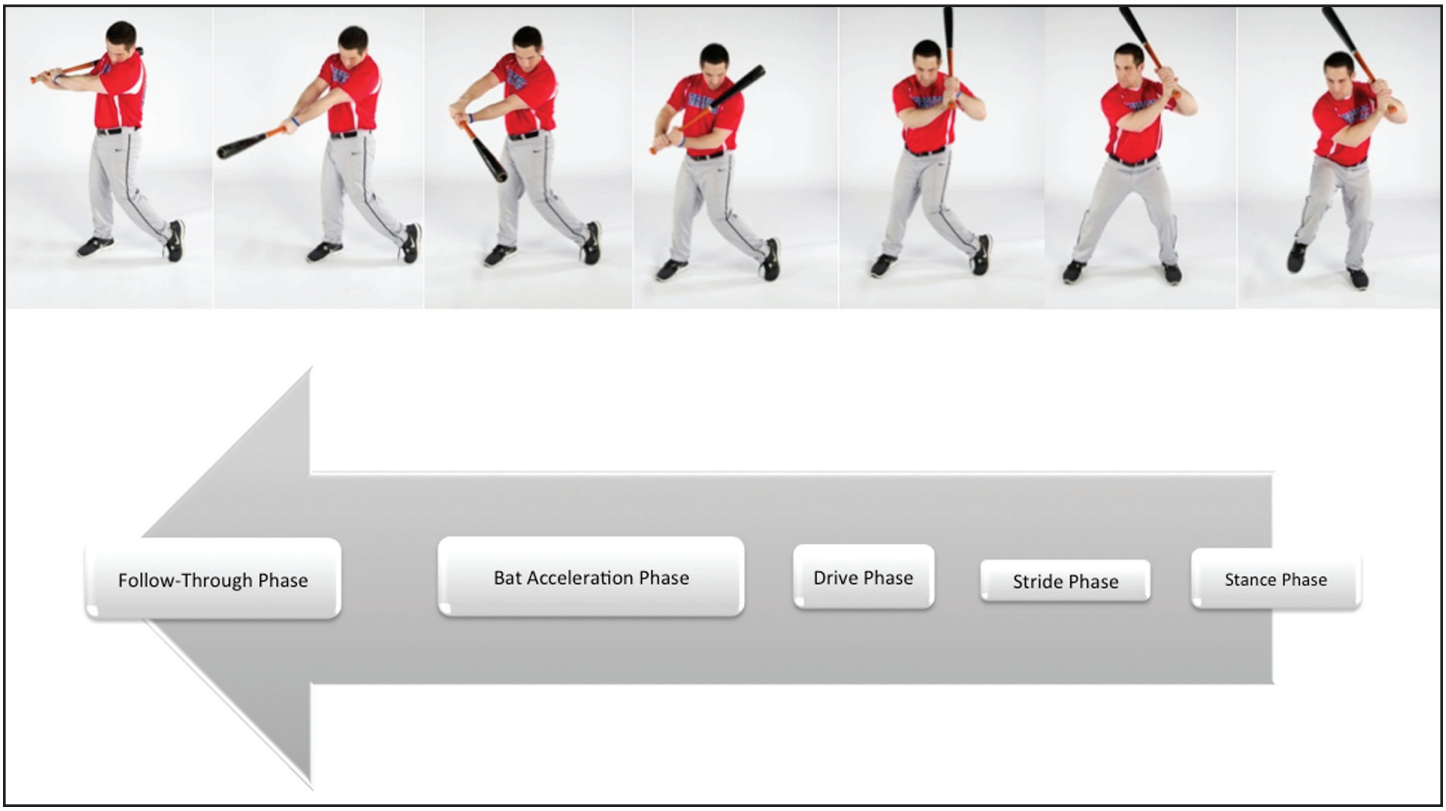

Figure 1. *The hitting cycle.*

tric stretch of the agonist muscles that produce the baseball swing. This period of loading must take place in order to aid with eliciting the stretch-shortening cycle.[22] When considering the baseball swing this period of loading normally occurs from the start of the stance phase and is completed at the drive phase; an eccentric movement must take place to set-up or aid in initiation of the swing. This loading phase is often referred to as the coiling or trigger mechanism by the baseball community.[23] The stored elastic energy is then released during the concentric contraction of the agonist muscles and transferred through the entire kinetic chain in a sequential order where different segments of the body are rotated.[23] When a large base segment starts to slow down or decelerate the other segments that are left gain velocity from that base segment assuming its' momentum.[23] The baseball swing acts in this manner with the lower extremities rotating first, followed by the trunk, then by the upper torso, then by the upper extremities, culminating the effort at ball contact. Further discussion of the hitting cycle will occur in the following sections.

STANCE PHASE

The initiation of the hitting cycle is first established at the start of the stance phase. The stance phase consists of the batter picking up their front leg and shifting their weight onto the back leg.[24] (Figure 1) This phase is completed when the stride foot is lifted off of the ground.[18] The process known as the loading period is initiated as soon as the stride foot is taken off of the ground. This mechanism is often referred to as the act of coiling because the hitter is moving different segments of the body away from the pitcher, which acts as the hitter's loading period.

STRIDE PHASE

The next phase of the hitting cycle is the stride phase. This phase takes place as the front leg advances toward the pitcher, linearly, and ends when the hitter's front leg makes contact with the ground.[18] A vital role in performance is finding lower extremity balance or a state of equilibrium. The hitter must find a position that is balanced between his base of support and center of gravity. As the player picks up the front leg during the stance phase, the hitter's

Table 2. *Significant difference found between youth hitters versus adult hitters. The below data was collected from Escamilla et al*[25]

Parameter	Youth Hitters	Adult Hitters
Stride Phase Length of Time (seconds)	0.29 ± 0.06	0.40± 0.07
Swing length of time (from stance phase to ball contact) (seconds)	0.51 ± 0.06	0.61± 0.07
Stride knee flexion angle (during start of bat acceleration phase) (degrees)	47 ± 19	70 ± 15
Percentage of swing involving upper torso angular velocity (%)	77 ± 10	88± 6
Bat linear velocity at Bat-Ball Contact (m/s)	25 ±3	30 ± 2
Youth defined as the ages of 12.3 through 17.1 years of age Adult defined as the ages of 19.9 through 24.5 years of age		

base of support goes outside of their center of gravity, the ground reaction force of the back leg is thus increased.[23] At this moment in time, the body will try to find a state of equilibrium by forcing itself in a linear motion forward, initiating the stride phase.[23] Proper stride length can aid with increasing performance during the hitting cycle. The starting position and the stance chosen influence the outcome of the swing. The stride should be long enough to promote linear movement forward and to aid with force production. Timing is crucial when it comes to the baseball swing: a stride that is either too long or too short could potentially produce detrimental effects for the swing. A shorter stride length could cause early initiation of the swing and a longer stride could potentially produce delayed activation of hip rotation, either one potentially reducing outcomes in performance. These subtle compensations could cause injury during the swing by disrupting the sequential timing of other body segments. The average stride length for hitters is normally 3.8 times greater than hip width and the position of the stride foot should be placed 12 degrees closed and facing 67 degrees toward home plate.[23] This closed position can be defined as the direction of the stride occurring toward home plate. This position is not to be confused with the preparatory phase prior to initiating the hitting cycle.

There are age-related differences that are apparent in youth versus adult hitters described by Escamilla et al[25](Table 2). Adult hitters were found to have a longer stride phase time versus youth ballplayers, allowing for additional time spent during their loading period, which creates an increase in bat velocity.[25] Youth ballplayers may produce a shorter stride length due to their lack of maturation, decreased muscular strength and shorter stature, when compared to adult players.[25] This could possibly be a potential area that predisposes younger players to injury. An optimal stride length will also allow for the best angular rotation during acceleration. Youth hitters also have a tendency to flex their stride knee less and produce a knee extension force at a decreased velocity when compared to adult hitters; potentially leading to reduced kinetic energy transferred up the body and decreased bat velocity production.[25] This could possibly cause another segment of the body to compensate and attempt to produce more force while approaching bat to ball contact ultimately leading to injury.

DRIVE PHASE

The next successive phase is the drive phase, which is considered from the point of foot contact into maximal bat lag or loading.[18] The loading period that started in the initial stance phase continues through

Table 3. *The Loading Period: degrees of motion per body segment. The below data was collected from Welch et al*[23]

Body Segment	Stance Phase (degrees)	Maximal Loading during Stride & Drive Phases (degrees)
Hip Rotation	11 - 25	28
Shoulder Rotation	16-44	52
Arm Rotation	45 - 75	58 - 86

The body has three segments that contribute to rotation: Hip segment is defined as a vector from the right to the left hip; Shoulder segment is defined as a vector from the right to the left shoulder and the arm segment is defined as a vector from the mid-shoulders to mid-wrists. The orientation of the trunk axis is defined in the transverse plane of motion where reverse rotation occurs in the opposite direction of bat-ball contact.
For example: For a right-handed hitter: clockwise rotation.

the stride phase until the upper extremities achieve complete bat loading. As the stride foot lifts off the ground in the stance phase the arms will produce an approximate reverse rotation of 60 degrees in the transverse plane away from the pitcher, however when the stride foot makes contact with the ground the arms will continue to rotate in this reverse direction approximately an additional 12 degrees achieving maximal bat loading.[23](Table 3) If the hitter cannot produce the adequate amount of reverse rotation then this could be a potential area for injury. This could eminently produce an inability to obtain the full stretch-shortening cycle thus causing decreased force production and other segments of the body to work harder to create bat velocity. The hips achieve their maximum loading at stride foot contact. The delay in upper segmental rotation aids in the ability to produce maximal bat acceleration in the successive phases of hitting.[18]

While the hitter assumes proper lower extremity positioning there is also an optimal placement of the upper extremities that must occur. Prior to initiating the baseball swing, the bat should be placed in a position that elicits the greatest mechanical advantage. Although many hitters start in different positions, when the drive phase is completed the bat should end in a position that adheres to a few principles: 1) The back elbow should have increased elbow flexion versus the front elbow,[25] 2) The bat should be placed at a position of approximately 45 degrees in the frontal plane and the bat should bisect the batter's helmet in half, 3) The back elbow should be down, 4) Both upper extremities should be positioned close to the hitter's body, and 5) The proximal interphalangeal joints of the hand of both upper extremities should align on the handle of the bat.[19](Figure 1)

BAT ACCELERATION PHASE

As the hitter moves into the next phase of the hitting cycle, an interaction must occur between linear movement and angular or rotational velocity. After the lead leg contacts the ground the body is in a closed kinetic chain.[23] At this point the elastic energy gained from the loading period is used to produce segmental rotation in different parts of the body.[23] The hips will turn first, followed by the trunk, gradually gaining angular velocity up the kinetic chain to produce contact between the bat and the baseball. [23] The bat acceleration phase takes place from the point of maximal bat loading until the bat makes contact with the baseball.[18] Once the stride foot/front foot has landed, the center of pressure that is created by the body is then outside of the center of mass (anterior to the body), it is at this moment that the hip segment starts to move toward the pitcher, which is often referred to as an uncoiling effect.[23] (Figure 1) The rotational velocity created at the hips and lower portion of the trunk is axially transferred up the kinetic chain to the upper segment of the body.[23] Near ball contact this upper segment continues to rotate, however rotation at the lower portion of trunk including the hips is minimal at this point.[18] To produce effective bat velocity each segment must rotate in a sequential manner, if a higher segment reaches its peak velocity before its

lower previous segment then the hitter has lost the ability to efficiently transfer kinetic energy up the kinetic chain. [23]

At ball contact, the hands should be placed out in front of the body with the elbows extended. Hitting coaches recommend keeping the hands above the barrel to optimize a direct path to the ball when approaching a contact position.[19] At contact position, the high amount of rotation occurring in the trunk forces the stride leg to become a blocking mechanism to assist the body to decelerate the linear movement previously accomplished.[23] For this blocking mechanism to occur, the stride leg has been found to be in a position of 15 degrees knee flexion and applies a total ground force of equal to 84 % of the hitter's body weight.[23] Once the bat has made contact with the ball, the baseball swing continues as the hitter finishes their swing entering into the follow-through phase of the hitting cycle.

FOLLOW-THROUGH PHASE

In order to achieve optimal effort, full hip rotation toward the pitcher needs to take place. Fleisig et al[18] have found that axial trunk acceleration once again increases as the hitter goes through the follow-through phase aiding in completion of full rotation.[18] Many youth players are often times told to overly rotate or "squash the bug" with their back foot, however, this could potentially reduce the hitter's ability to shift their weight forward reducing the amount of hip rotation that needs to occur during the follow-through phase. Pointing the laces of the rear shoe toward the pitcher can aid in achieving this full rotation.[19]

The proper sequence of each of these phases helps with producing an efficient swing and from a rehabilitative standpoint can aid with observing biomechanical inadequacies. When it is time for the patient to introduce hitting, the rehabilitative specialist should observe these key areas of focus and implement them as needed. Three-dimensional motion analysis has previously been used to observe the hitting cycle and should be considered to look for subtle motion insufficiencies that cannot be observed naturally.[18] Even collaboration with a qualified hitting coach may be beneficial. Prior to such considerations, each clinician should determine when it is safe for the patient to return to sports-related functional tasks.

READINESS TO RETURN TO SPORT

The purpose of this proposed interval hitting progression program is to gradually introduce the demands from hitting, in order to avoid re-injury. The overall goal of any progression program is to introduce progressive loads that focus on gradually increasing intensity and duration of effort.[26] Prior to entering such a program the patient must meet certain criteria. Assessment measures must be used to determine if an athlete's current status is at the level needed to start hitting. Due to the high velocity of movement and the complex sequence of events that take place, hitting can be considered an activity that requires a higher level of function. Assessment of function can be broken down into three areas: impairment measures, patient-report measures, and physical performance measures.[27] Each one of these areas contributes to the bigger picture of performance. To begin an interval progression program, such as the one proposed in this commentary, the athlete must be evaluated through all three of these of areas.

Examination regarding the patient's concordant injury must show adequate range of motion to meet the demands of the hitting cycle, minimal to no pain, lacking tenderness to palpation, and adequate strength needed for the activity.[6, 28, 29] To initiate a sports-related activity, it is recommended that the involved extremity should meet eighty percent of strength performance compared to the uninvolved extremity.[30, 31] However, manual muscle testing has been found to be unreliable; thus, the use of hand-held dynamometer or electromechanical dynamometers is recommended.[32, 33]These impairment measures provide the initial framework or building blocks for progression into performance.

When considering which impairment measures are most beneficial to the baseball swing, the clinician must place emphasis on which muscle groups are most active and how many degrees of motion are required at each body segment during each phase of the hitting cycle. Previous electromyographical studies reveal that there is a certain sequence of muscle

Table 4. *Motion required at each body segment in order to complete the hitting cycle. All data are reported in degrees. The below data was collected from Welch et al[23], and Fleisig et al[18]*

Body Segment	Degrees of motion
Stance leg knee flexion	19-57
Stride leg knee flexion	6-55
Back elbow flexion	48-134
Front elbow flexion	29-97
Trunk extension (-)/flexion (+)	(- 15) – (+27)
Trunk lateral flexion (-) away/(+) towards pitcher	(-10) – (+25)
Maximal trunk rotation at ball contact	55

Each recorded value is along the X-axis; position from home plate to the pitching rubber; parallel to the batter's box. (+) is toward the pitching rubber and (-) value is toward home plate

activation that takes place.[34] As previously mentioned rotation occurs at different areas of the body with the first being from the lower extremities then moving up the entire kinetic chain. For instance the hamstrings and gluteus maximus appear to be most active during the drive and bat acceleration phases.[34] The quadriceps have also been found to be active in later stages of the hitting cycle signifying their importance as the stride's leg blocking mechanism.[34] The abdominals, specifically the obliques, and erector spinae musculature play a crucial role activating at the start of foot contact to the end of the hitting cycle.[34] Not only is adequate strength necessary to aid with reduction of re-injury, but range of motion also plays a significant role. A hitter must have adequate axial trunk rotation throughout their body and possess the proper lower and upper extremity motion to complete the baseball swing.[18, 23] (Table 4) Proper knee, trunk and elbow motion is necessary as well to obtain optimal performance. (Table 4) Inadequate motion or strength at any of these body regions could cause compensation from another area of the body and could potentially lead to injury. Therefore, it is important to examine the athlete with an eye for these potential deficits in an athlete who would like to return to baseball.

Impairment measures alone cannot determine whether an athlete is ready to return to sport. Therefore, the clinician must also assess physical performance. Physical performance measures are considered tests that challenge a physical action that is necessary to complete a particular task.[35] These performance measures are assessed in a standardized manner and are repeatable by the tester.[35] These types of tests are typically used to assess limb symmetry and to determine a patient's current probability for sustaining an injury.[36] To the author's knowledge there have not been any performance measures established specifically for return to hitting. But, a clinician may select a performance measure based on the injured body part and the objective of the test. Since weight shifting occurs on the stance and stride legs dynamic balance plays a significant role; therefore tests such as the Y-Balance test (YBT) can be useful.[37] During the acceleration phase there is a significant amount of trunk or torso rotation that uses the entire kinetic chain. Previous research has used simulated medicine ball throwing for hip-torso-arm rotational power which has shown to be a useful measure.[38, 39] The two tests that showed validity for torso rotational power were the whole body medicine ball throw, or otherwise known as the hitter's throw, and the seated medicine ball toss.[38, 39] A 1-kg medicine ball is used for these tests and the maximal distance the athlete can throw the ball using rotational forces is recorded.[40] This data can be used as a physical performance measure to determine progress during rehabilitation or tolerance of the hitting motion. If a clinician chooses not to perform one or more functional performance tests, at the very least the patient should be able to swing a bat without pain or compensation prior to beginning the return to hitting program.

The final part of the functional assessment relies on the patient's self-perception of functional ability. Patient-reported outcome measures are used to give a subjective report regarding what the patient perceives they are able to do. These can be useful tools to

aid with determination if an athlete is mentally prepared to participate or if there is some apprehension to start a progression program. To the author's knowledge, no patient-report measure currently exists for hitting. However, other patient-report measures exist for particular injured body parts or for those experiencing kinesiophobia. Many patient-reported outcome measures can be found in the literature: Fear Avoidance Belief Questionnaire,[41] The Tampa Scale of Kinesiophobia-11,[42] Foot and Ankle Ability Measure, [43] Hip Outcome Score, [44] Lower Extremity Functional Scale, [45] and Kerlan-Jobe Orthopaedic Clinic Shoulder & Elbow Score.[46] The clinician should use valid and reliable measures that appropriately assess the patient's abilities or feelings based on their condition or site of injury. These patient-reported outcome measures can assess patient progress and help determine if the patient feels ready to begin the return to hitting program.

THE INTERVAL HITTING PROGRESSION PROGRAM

There is a vast array of individual strategies that can be used with the baseball swing; however, it is pertinent that proper mechanics be introduced to the patient in a rehabilitation setting. An alteration in hitting mechanics can produce an increased potential for injury, a single example would be changing the angle of the shoulders; therefore, appropriate mechanics can aid with the reduction of injury.[17] Once proper mechanics are obtained, the clinician can then introduce the outlined interval hitting progression program.

The interval hitting progression program proposed in this commentary uses percentage of effort. (Appendix 1) It is important to keep in mind that estimation of percent effort can be perceived differently from one athlete to the next.[47] Therefore, the rehabilitation specialist must understand the cognitive aspect of the athlete when describing effort.

The warm-ups found in Appendix 2 are used to simulate the actual hitting motion through exercise selection. Many baseball players use weighted bats prior to hitting in practice and during games; however, the selection of these devices have not been shown to improve bat velocity.[48] The application of such a device should not be used as a warm-up tool. Increasing the resistance of the bat may prove to be provocative to the injury that the athlete is trying to overcome. Therefore, the use of such a device is discouraged. Exercises that focus on total body rotation through movement should be used instead.

The proposed protocol for hitting progression moves from hitting off of a tee, to soft toss, then finally to simulated hitting. The purpose behind this progression is to slowly introduce an environment that begins at a lower intensity by having the baseball first placed in a fixed position then progressing to the baseball in trajectory with soft toss then finally followed by an increase in velocity.

The chosen change in ball location established for Phase 2, soft toss, was used to simulate differences in placement of pitches that may occur while hitting in a game. Higuchi et al.[49] proposed that a hitter may be able to visually pick up on the velocity and trajectory of the ball as soon it is released by the pitcher. If the hitter is able to pick up on different target positions, such as the height of the pitch, then there could be an increase in performance.[49] Soft toss is considered an effective drill for most hitters and used by many baseball experts. [19] This normally consists of the hitter's teammate or coach kneeling approximately thirty to thirty-five feet away from the hitter, facing the hitter at an angle of 45 degrees and tossing the ball in an underhand action. Some coaches prefer to kneel behind the hitter at a safe distance away to provide differences in ball location for outside or inside pitches, while others prefer to have the hitter angled away or toward their teammate/coach to simulate this change in ball location. Either way the hitter, as well as the person performing each toss, should familiarize themselves with their preferred technique prior to implementation.

Timing of sequential body segments plays a substantial role in the outcome of the swing. To elicit the stretch-shortening cycle a hitter must have the proper loading period that is appropriately timed to improve force production. With the randomization of how pitches are delivered during play, a hitter must practice under similar conditions in order to accommodate for an increase or decrease in pitch velocity. This interval hitting progression program captures this concept in Phase 3.

Progression within this program provides a physical stimulus designed to promote adaptation of healing tissue. This stimulus, like any other physical conditioning program, is often referred to as the overload principle.[50] Muscular soreness can be a by-product of this change and it is often described as a muscle feeling stiff, tender and aching to touch or when applying movement.[51-53] Eccentric-based exercise can produce the associated soreness which has previously been reported to last forty-eight hours.[54-56] To avoid any additional injury, proper rest guidelines must be initiated. For progression in this program, the patient should follow the established soreness rules. (Appendix 1) These soreness rules have been adapted from previous literature to fit the needs of this specific progression program.[26] These rules provide the patient the ability to modify progression according to the symptoms that they experience. If muscular or joint stiffness and or tenderness is present then the soreness rules should be observed. It is important to note that the sensation of soreness is different than the sensation of pain. If the patient is complaining of concordant pain experienced at the site of initial injury that lasts longer than the expected time frame for muscular soreness, the clinician should reevaluate the patient's symptoms and alter or postpone the return to hitting program. If no soreness is present then the patient is instructed to move onto the next step in the hitting progression program and this should occur on the next day of training. Each training day should have one day of rest in between steps to ensure proper recovery and adaption to the stimulus of hitting. All other exercises, such as a home exercise program, should be performed on the same day after the patient has completed hitting. These recommendations have been adapted from other previously established interval sport programs.[6]

CONCLUSION

Since hitting is a complex activity requiring coordinated motion of the entire body, any injury may impact a patient's ability to swing a bat. Similar to the return to throwing programs that exist, this interval hitting program guides the clinician from when the patient is ready to begin hitting through a full return to sport. Sports-related exercises should have been implemented in a pain-free environment, (including plyometric exercises) prior to starting this program. The proposed interval hitting progression program should be used as a method to quantify progression and may reduce the chance of injury from occurring. Future research should be conducted that studies the use of this program on injured baseball players as well as other rehabilitation models that are specific to hitting.

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APPENDIX 1

Interval Hitting Progression Program

Instructions:

- *Each step should be performed in succession; starting with Step 1 performed on Day 1,Step 2 performed on Day 2, and so forth*
- *Each training day should have one day of rest in between steps to ensure proper recovery and adaption to the stimulus of hitting.*
- *All other exercises, such as a home exercise program, should be performed on the same day and after the completion of hitting.*
- *Perform Lower & Upper Extremity Warm-ups prior to performing each step. Please refer to Appendix 2 for these warm-ups*
- *Please follow the soreness rules for advancing to each step included in this Appendix*

Phase 1	Basic: Hitting off of Tee
Step 1 ▪ Tee set-up: ball placement middle of plate and at waist height ▪ Perform 25 swings at 50% of effort ▪ Concentration should be placed on addressing mechanics of the baseball swing	

Phase 1	Hitting off of Tee:	Direction of Challenge	
Step 2: ▪ Tee set-up at waist height ▪ 50% Effort	**Step 3**: ▪ Tee set-up at waist height ▪ 75% Effort	**Step 4**: ▪ 75% Effort	**Step 5**: ▪ Repeat Step 4 ▪ 90 to 95% Effort
15 swings middle of plate	15 swings middle of plate	20 swings middle of plate consisting of: 1. 5 swings letters/chest height 2. 10 swings waist height 3. 5 swings just above knees	20 swings middle of plate consisting of: 1. 5 swings letters/chest height 2. 10 swings waist height 3. 5 swings just above knees
15 swings tee set-up inside corner of plate	15 swings tee set-up inside corner of plate	20 swings inside corner of plate consisting of: 1. 5 swings letters/chest height 2. 10 swings waist height 3. 5 swings just above knees	20 swings inside corner of plate consisting of: 1. 5 swings letters/chest height 2. 10 swings waist height 3. 5 swings just above knees
15 swings tee set-up outside corner of plate	15 swings tee set-up outside corner of plate	20 swings outside corner of plate consisting of: 1. 5 swings letters/chest height 2. 10 swings waist height 3. 5 swings just above knees	20 swings outside corner of plate consisting of: 1. 5 swings letters/chest height 2. 10 swings waist height 3. 5 swings just above knees

Phase 2	Basic: Soft Toss
Step 6 ▪ Soft toss (underhand toss) 25 swings at 50% effort with partner, set-up at 45 degrees away from hitter. Hitter will be hitting into net or cage ▪ Placement of ball should be at waist and middle of plate ▪ Concentration should be placed on addressing mechanics of the baseball swing	

*Prior to performing each step in phase 2 perform 10-15 swings off of tee as a warm-up

Phase 2	Soft Toss:	Direction of Challenge	
Step 7: ▪ 50% Effort	**Step 8**: ▪ Repeat Step 7 ▪ 75% Effort	**Step 9**: ▪ 75% Effort	**Step 10**: ▪ 90 to 95% Effort
10 swings with ball placed at waist height &middle of plate	10 swings with ball placed at waist height & middle of plate	30 swings middle of plate consisting of: 1. 10 swings waist height, middle of plate 2. 10 swings ball chest/letters height, middle of plate 3. 10 swing ball just above knees, middle of plate	30 swings middle of plate consisting of: 1. 10 swings waist height, middle of plate 2. 10 swings ball chest/letters height, middle of plate 3. 10 swing ball just above knees, middle of plate
10 swings with ball placed at letters height & middle of plate	10 swings with ball placed at letters height & middle of plate	10 swings with ball placed for outside corner	15 swings with ball placed for outside corner
10 swings with ball placed just above the knee & middle of plate	10 swings with ball placed just above the knee & middle of plate	10 swings with ball placed for inside corner	15 swings with ball placed for inside corner

NOTE: An "L" screen should be used for protection while performing certain soft-toss positions Please refer to Appendix 3 for Soft Toss Variation.

Phase 3	Basic: Simulated Hitting
Step 11 ▪ This phase should be performed in a batting cage or on the field ▪ 30 swings of fastballs consisting of: 10 inside, 10 outside, 10 middle of plate ▪ Height of pitch can be left randomized ▪ Perform at 50% effort	

*Prior to performing each step in phase 3 perform 10-15 swings of soft-toss
*The partner should use an "L" screen for protection

Phase 3	Simulated Hitting:	Pitch Type Challenge
Step 12: ▪ 75% Effort ▪ In cage/on field	**Step 13**: ▪ 75% Effort ▪ In cage/on field	**Step 14**: ▪ 90-100% Effort
25 swings against fastballs; Randomized placement	25 swings against fastballs; Randomized placement	25 swings against fastball; Randomized placement
15 swings at change-ups; Randomized placement	15 swings against change-ups; Randomized placement	15 swings against change-ups; Randomized placement
	For ages 14 and above add in 15 swings against curveballs	For ages 14 and above add in 15 swings against curveballs

*An "L" screen should be used for protection for the person throwing

Soreness Rules (Adapted from Axe et al)[26]	
Soreness Rules for progression:	***Interval Hitting Progression Program***
If there is no soreness present	Progress to the next step on the next day of training
If soreness occurs during the warm-up and then goes away in the first 15 swings	Repeat the previous step
If soreness occurs during the warm-up and continues during the first 15 swings	Stop, take 2 days off and upon returning drop down 1 step
If soreness occurs for more than hour after swinging	Take 1 additional day off and repeat the most recent stage

APPENDIX 2

Warm-ups prior to interval hitting progression program

Figure 2. *Rotational Arm movements*
The athlete starts with both palms pointed toward the ceiling, then the feet are rotated to the right and the left arm will perform internal rotation (keeping arms shoulder level). Rotate to the opposite direction performing the same movement. ** Perform 2 sets of 10 repetitions each side.

Figure 3. *Side Lumberjack Chops*
First pivot and rotate away from the direction you will be actually performing the lumberjack chop. Use a light ball (such as a volleyball); The ball should be above your head with both arms extended and the back foot should be pivoting facing this same direction.
Then take the medicine ball from the top of this motion in a diagonal pattern/across the body and perform a lunge in the opposite direction while pivoting again on both legs (back and head should be straight and be sure that the front knee is behind your front foot
**Perform 2 sets of 10 repetitions each side

Figure 4. *Hitters Throw*
Assume a batting position and hold the ball as if you were holding a baseball bat.
Then throw a light ball (such as a volleyball) simulating the baseball swing toward a wall or open field.
**Perform 2 sets of 10 repetitions each side