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Review Article

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Acute Effects of a Resistance Tubing Training Device on Baseball Swing Kinematics

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Abstract

Objective: The purpose of this study was to assess the acute kinematic changes that occur on the youth baseball swing following use of a resistance tubing training device.

Methods: Kinematic data were collected on 10 subjects (13.2 ±1.9 years of age; 161.8 ±17.4 cm; 54.4 ±15.9 kg) at 240 Hz using Flock of Birds electromagnetic tracking system (TrackSTAR™, Ascension Technologies Inc., Burlington, VT., USA) synced with The MotionMonitor® (Innovative Sports Training, Chicago, IL., USA). Participants were required to hit 5 baseballs off of a tee with intention to hit line drives up the middle. At the completion of a three-minute rest, the participants were equipped with the resistance tubing training device and asked to perform 20 low effort dry swings. Subjects were then asked to hit 5 baseballs off a tee while wearing a resistance tubing training device and then 5 more off the tee without wearing a resistance tubing training device. Data were analyzed for the pre-device and post-device hits.

Results: A repeated-measures multivariate analysis of variance revealed no significant differences pre-resistance and post-resistance tubing training device for center of mass over base of support (COM over BOS) or segmental velocities (Λ=0.68, $F_{4,6}$=0.72, p=0.608).

Conclusion: The absence of a significant decrease in segmental velocities could expose a resistance tubing training device as an appropriate warm-up tool and beneficial training aid. Because the resistance tubing training device is not detrimental to segmental velocities in the acute sense, it should be considered a practical sport-specific training aid.

Keyword: Baseball; Baseball swing; Batting; Hitting; Kinematics; Training aid; Youth baseball

Introduction

With the continual quest of improvement, due to science and technology in today's generation, positive reinforcement is imperative. Youth baseball players seek success in their game performance in order to maintain high self-esteem and appreciation from their coach. For years, resistance training has been used by athletes to improve sports performance. When specifically examining the sport of baseball, lumbopelvic-hip complex (LPHC) improvements in strength have been related to increased bat swing velocity [1,2]. Additionally, strengthening programs that have emphasized trunk rotation, lower extremity strength, and power have yielded increases in swing speed [3-8]. Along with the notion of increased LPHC strength and performance improvement, a link between balance training and power production has also been found [9]. In hitting, it is essential to maintain balance throughout the swing to obtain optimal movement timing [9]. Resistance training that focuses on balance may prove beneficial for hitters to optimize timing, especially on off-speed pitches. Because most professional baseball hitters utilize the same loading technique on all their swings, pitchers will throw off-speed pitches in attempt to offset the hitters weight distribution and subsequent sequential timing [10]. Any training that assists in the development of a more stable base could prove helpful for the hitter when facing a deceptive pitcher. Resistance training can aid in balance during all forms of movement and decrease the time needed for neuromuscular system to warm-up.

To achieve optimum performance, the neuromuscular system needs repeated stimulation to perform at speeds demanded during competition. In attempt to engage the neuromuscular system, a baseball hitter will emulate in-game swing mechanics while in the on-deck circle. The importance of this conventional hitting warm-up routine on swing performance has been assessed utilizing various warm-up devices [11-13]. In an examination of different bat weights in baseball and softball, it was found that warming-up with a very light or normal bat weight resulted in maximum swing velocity as compared to warming up with a heavy bat weight [11,14]. However, it has also been reported that using a bat weight or other training aids to warm-up have no influence on swing velocity [13]. Although the benefits of bat swing warm-up regimens are conflicting [11-13], the collective conclusion is that athletes should choose the warm-up implement with which they are most comfortable.

While swing velocity is a kinematic variable that will impact the success of a baseball or softball hitter, there are other kinematic variables that also influence swing movement efficiency. For maximum bat swing velocity it is recommended that one utilize the entire kinetic chain of the legs, trunk, and shoulders for efficient rotational kinetic link movement [15]. Thus, a sport specific movement for warm-up and training purposes will have the most carry over to swing velocity [15-17]. In an examination of lower extremity kinetics on baseball swing performance, it has been suggested that the lower extremity should shift toward the pitcher using hip and stride knee torque in attempt to reach high bat and hand speed [18]. Additionally, optimization of lower extremity joint torque timing is necessary for peak angular velocity [10,19]. Thus, reiterating the need for coordinated and efficient movement mechanics for optimal bat swing velocity [10].

While the effect of numerous training aids on bat speed velocity has been determined, the effect on other kinematics such as segmental speeds is not known [11-13]. Of the training aids that have been examined, most have utilized some type of weight that is applied to the bat, however a resistance tubing training device is a training aid that applies resistance to an athlete instead of altering the weight of the bat. The resistance tubing training device considered in this study is the Pitcher's Nightmare Swing Trainer, which is a resistance training aid for the baseball or softball swing, designed for the on-deck circle and

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practice to improve a hitter's positioning and swing efficiency during an actual game. Swing efficiency can be assessed through the examination of the center of mass over base of support (COM over BOS) and angular velocities of the pelvis, trunk, and separation between pelvis and trunk [20,21]. Therefore, the purpose of this study was to assess the acute kinematic changes that occur on the youth baseball swing following use of a resistance tubing training device. Our hypothesis was that the resistance tubing training device would be a potential on-deck swinging apparatus for baseball hitters seen by no detrimental kinematics such as an altered center of mass over base of support and decreased pelvis angular velocity, torso angular velocity, and separation angular velocity.

Methods

Experimental approach to the problem

All participants reported to the Sports Medicine and Movement Laboratory without engaging in prior exercise for the day. Because the resistance tubing training device is a resistance tubing training aid designed for baseball and softball hitters, we wanted to observe the acute effects of resistance tubing training device usage on COM over BOS and segmental velocities in a baseball swing. A repeated-measures pre-experimental design was used to determine the acute changes of COM over BOS, pelvis segmental velocity, trunk segmental velocity, and separation segmental velocity upon a baseball swing following the use of the resistance tubing training device.

Participants

Data were collected on 10 youth baseball athletes (13.2 ±1.9 years of age; 161.8 ±17.4 cm; 54.4 ±15.9 kg). Using a G power 3.1.9.2 and pilot data from this study, we found an effect size of 0.53. Using a power of 0.8 we found a total sample size of 10 people. All participants were actively participating on a competitive baseball team, in good physical condition, and had no injuries within the last six months. Auburn University's Institutional Review Board approved all testing protocols. Informed written consent and parental assent were obtained prior to testing.

Procedure

Kinematic data were collected at 240 Hz using Flock of Birds electromagnetic tracking system (TrackSTAR™Ascension Technologies Inc., Burlington, VT., USA) synced with The MotionMonitor® (Innovative Sports Training, Chicago, IL., USA). Fourteen electromagnetic sensors were attached to the following locations: (1) the posterior/medial aspect of the torso at T1, (2) posterior/medial aspect of the pelvis at S1, (3-4) bilateral distal/posterior aspect of the upper arm, (5-6) bilateral flat, broad portion of the acromion of the scapula, (7-8) bilateral distal/posterior aspect of the forearm, (9-10) bilateral distal/lateral aspect of the upper leg, (11-12) bilateral distal/lateral aspect of the lower leg, (13) dorsal aspect of the 3rd metatarsal of the lead leg and (14) dorsal aspect of the 3rd metacarpal of the top hand. Medial and lateral aspects of each joint were identified and digitized, with joint centers being calculated by the midpoint of the two points digitized.

The error in determining position and orientation of the electromagnetic sensors with the current calibrated world axis system was less than 0.01 m and 3°, respectively. Intra-rater reliability of digitization using the technique described below, which was determined during a pilot study of 5 active individuals, was an ICC (3,k) of 0.75 to 0.93 for all measurements. In order to ensure accurate identification and palpitation of bony landmarks, the participant stood in anatomical neutral throughout the duration of the digitization process so their body segments could be defined. Raw data regarding sensor position and orientation were transformed to locally based coordinate systems for each of the representative body segments. For the world axis, the Y-axis represented the vertical direction, in the direction of movement was the positive X-axis, and orthogonal to X and Y to the right was the positive Z-axis. Position and orientation of the body segments were obtained using Euler angle sequences that were consistent with the International Society of Biomechanics standards and joint conventions [22]. More specifically, ZX'Y" sequence was used to describe pelvis and trunk motion and YX'Y" sequence was used to describe shoulder motion. All pelvis and trunk motion were captured in reference to the world axis.

The shoulder and hip joint centers were estimated using the rotation method, as has been shown to provide accurate positional data [23,24]. The shoulder joint center was calculated from the rotation between the humerus relative to the scapula, while the hip joint center was calculated from the rotation of the femur relative to the pelvis. The joint center variation in measurement had to have a root mean square error of less than 0.001 m to be accepted. A fourth-order Butterworth filter with a cutoff frequency of 13.4 Hz was used to smooth raw data of each digitized point [25,26].

Once all sensors were secured and participant digitized, participant was given unlimited time to warm up. Participants were instructed to swing off a tee and hit line drive up the middle of the cage until they felt game ready. Tee location was participant determined in order for line drives up the middle of the cage to be obtained. Following the warm-up, participants were required to perform five swings with intention to hit hard line drives up the middle of the cage. Following five solid hits off of the tee, the participant had three minutes to rest. Rest time was implemented to negate any carryover or fatigue of previous swings. At the completion of the three-minute rest, the participants were equipped with the resistance tubing training device. Participants were then instructed on the resistance tubing training device and asked to perform 20 low effort dry swings in an effort to assimilate being on-deck. A dry swing was counted when the participant swung the bat and no ball contact was made. No data were recorded for these swings, as the purpose was to initiate any acute training affects that might take place while on the on-deck circle. After the 20 dry swings, the participant was asked to hit 5 more baseballs off a tee with the intention to hit hard line drives up the middle while wearing the resistance tubing training device. Last, the participant was instructed to remove the resistance tubing training device and hit five hard line drives up the middle off of the tee. Data were analyzed for the pre-device and post-device hits. Of the five hits for both pre and post hits, repetitions two through four were average and selected for analysis. The first and fifth repetitions were disregarded in order to mitigate the Hawthorne effect.

Three events of the hitting motion were selected for analysis: lead foot off the ground, lead foot contact with the ground, and ball-bat contact [20]. Lead foot off the ground was identified as the first frame in which the lead foot was no longer in contact with the ground. Lead foot contact with the ground was identified as the first frame when the lead foot made contact with the ground. Ball-bat contact was identified as the frame immediately following peak hand velocity. COM over BOS was averaged across the whole swing starting at foot off and ending at ball contact. The max value for pelvic angular velocity, and torso angular velocity was taken to be analyzed. Separation angular velocity was defined as torso angular velocity minus pelvic angular velocity and was acquired from the event of foot contact.

Statistical analyses

Repeated-measures multivariate analysis of variance was conducted to determine if the position of the center of mass over base of support, pelvic angular velocity, torso angular velocity, and separation angular velocity differed upon usage of a resistance tubing training device. Data were analyzed using Statistical Package for Social Science (SPSS) software (version 23; SPSS Inc., Chicago, IL., USA) with an alpha level set a priori at $p \leq 0.05$.

Results

A repeated-measures multivariate analysis of variance revealed no significant differences pre-resistance and post-resistance tubing training device for COM over BOS or segmental velocities (Λ=0.68, $F_{4,6}$=0.72, p=0.608). About 22% of the variance in the dependent variables tested was explained by the usage of the resistance tubing training device (ω2=.22). See Table 1 for descriptive statistics.

	Pre-A resistance tubing training device	Post-A resistance tubing training device
COM over BOS (%)	32.31 (6.57)	31.42 (6.54)
Pelvic angular velocity (°)	720.31 (111.44)	733.22 (107.73)
Torso angular velocity (°)	897.19 (108.51)	908.52 (110.70)
Separation angular velocity (°)	-135.61 (93.73)	-154.30 (70.34)
Note: COM over BOS is a 0-100 percentage scale, with 0 meaning all of the center of mass is on the participant's back leg while 100 means the center of mass is all over the participant's front leg. Separation Angular Velocity was taken at foot contact and found as Torso Angular Velocity minus Pelvic Angular Velocity.		

Table 1: Descriptive statistics for pre/post variables listed as mean (SD).

Discussion

The purpose of this study was to assess the acute kinematic changes that occur on the youth baseball swing following use of a resistance tubing training device. Our hypothesis that the resistance tubing training device would be a potential on-deck swinging apparatus was confirmed by no observable changes in the hitter's center of mass over their base of support, pelvis angular velocity, torso angular velocity, and separation angular velocity after use of the device. While no advantages in kinematics were noticed in this study, none were expected following a short protocol comparable to an on-deck experience. Improvements in kinematics would need to be assessed following a longer intervention.

Although the resistance tubing training device is located only on the backside of the hitter, no significant alterations regarding center of mass location over base of support or segmental velocities were observed. Results seen in a previous study by Laughlin and colleagues indicated that the placement of resistance has an effect on swing kinematics [27]. Our results indicate that resistance placed on the backside of the hitter for a few swings, such as experienced while the hitter is waiting on-deck, will cause no acute kinematic changes to a regular swing. With the resistance tubing strapped below the backside knee and elbow, potential for the device to cause the hitter to lean over their back leg existed. Common belief is that for a hitter staying more posterior, over their base of support as defined in the current study, the swing would be more rotational than linear [12]. The current results indicate that using a resistance tubing training device does not acutely lead to greater rotational segmental velocity for a hitter, which implies no effect on the rotational versus linear baseball swing conundrum.

Previous studies have indicated that acceptable warm-up tools of the past, the donut or additional bat weight, decreases bat swing velocity [11,12]. A strong relationship has been found between pelvis angular velocity, torso angular velocity, and separation velocity with linear velocity of the bat tip at ball contact [28], thus reiterating the need to examine segmental velocities during the bat swing. Although the current study did not reveal any significant differences in segmental velocities after the use of a resistance tubing training device, these results could still prove beneficial. The absence of a significant decrease in segmental velocities could expose a resistance tubing training device as an appropriate warm-up tool and beneficial training aid.

Even without significant impact on segmental velocity, participants still acknowledged that there was some effect from the resistance tubing training device causing the bat to feel lighter or even weightless after usage. This positive reinforcement of swing mechanics could benefit a youth athlete by improving their self-esteem when they step on the field of play. Future research should examine if the resistance tubing training device alters muscle activation of the swing, has a post-activation potentiation effect, and makes the swing more efficient. Also, future studies should observe the changes to a hitter's swing following training use of a resistance tubing training device. Next, an intervention study on the training effect of the resistance tubing training device should be conducted to see its effects as a practice tool.

While this study provides insight into the use of a resistance tubing training device as a warm-up training aid, several limitations to this study do exist. One limitation is the lack of an actual bat velocity variable to determine the resistance tubing training device effectiveness. A convenience sample with limited sample size was used for this study and may not translate across the entire youth baseball population. Another limitation includes a cross-sectional laboratory design that only examined swinging off of a tee. Use of a resistance tubing training device as a warm-up and training aid for more game like situations should be considered with future research.

Conclusion

Players and coaches should view a resistance tubing training device as an option for an on-deck tool to assist hitter's in the preparation for there at-bat. Because the resistance tubing training device is not detrimental to segmental velocities in the acute sense, it should be considered a practical sport-specific training aid.

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