Predictors of Personal Best Performance in the Hammer Throw for U.S. Collegiate Throwers

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Abstract

The purpose of this study was to investigate the variables that contributed most to maximum throwing distance in the hammer throw event in track and field. A 41-item survey instrument was developed to collect data regarding national level collegiate hammer throwers throughout the United States. Multiple regression analysis for hammer throw personal record (PR) yielded a significant model \( r = 0.811, p \leq 0.001 \) with the following predictors: number of throws per year, number of years throwing the hammer, NCAA division, back squat, and type of hammer technique. The model explained in excess of 65% of the variance in hammer technique among the respondents \( r^2 = 0.658 \). These results provide quantitative information for coaches and athletes involved in the hammer throw event about the importance of years of experience, volume of training and strength levels. Furthermore, the results may provide some insight into the obstacles and barriers limiting the development of US hammer throwers.

Key words: coach education, hammer throw, strength, throwing, track and field.

1. Introduction

The hammer throw is an athletic track and field throwing event; the objective is to throw a heavy steel ball attached to a wire and handle (with a maximum length of four feet) as far as possible. The hammer throw requires a vast amount of technical expertise (Dunn and McGill, 1991). Combining strength, balance, timing, and the necessity of near-perfect technique, the hammer is definitely one of the most exciting and artistic of the field events. The weight of outdoor competition hammers used today in the Olympics and nationally accredited (IAAF) track and field events are 4 kg for women and 7.26 kg for men (Connolly, 2006). Like other throwing events in track and field such as discus and shot put, competition in the hammer is decided by who can throw the implement the farthest. Athletes gain maximum distance by winding the hammer around the front of the body to set up the circular motion. Athletes then apply force to the ball and pick up speed by completing one to four (heel left foot) (ball right foot) turns in a seven foot concrete circle (Connolly, 2009). Most throwers turn three (three heel turns) or four (one toe and three heels) times, depending on the kind of technique used. The ball moves in an
elliptical path prior to release, gradually increasing in velocity on each turn, with the high point of the ball orbit toward the sector, or marked landing area; the low point of the hammer is at the back of the circle away from the sector. The thrower then releases the ball at the front of the circle. The three most important biomechanical factors for a long throw are the velocity (speed of the ball), angle of release and height of release (Connolly, 2009). In recent years, competition in the hammer throw has developed to such a high level that no coach can afford to neglect the application of scientific principles when constructing a training plan for athletes in the event (Judge et al., 2008). The hammer throw has changed considerably since its origin; equipment changes (such as more precisely-manufactured hammers and smooth-soled shoes that permitted faster spinning), training methods and throwing distances (now in excess of 280 feet for the best men and 250 feet for the best women in the world) (Dunn and McGill, 1991). By utilizing this critical scientific approach to the hammer throw event, the throws coach will be able to determine more accurate adjustments and devise training stimuli to better accommodate the athlete while ensuring improved and successful performances. Objective data on the hammer throw can and should be quantified and studied by researchers and trained coaches as part of the scientific approach (Judge et al., 2008).

The definitive goal of training hammer throwers is the functional reconstruction of the athlete, resulting in enduring adaptation and preservation of the training effect (Judge, 2007). When considering the variables that make up the training programme (i.e. training load, training volume, exercise selection, and training frequency) the distribution of each in the plan could depend upon the athlete’s training age, his or her strengths and weaknesses, the phase of the training year, as well as many other factors (Judge, 2007). For a hammer thrower there must be a balancing of the training loads with restorative and prophylactic measures (Judge, 2008). In the United States, there is an almost complete reliance on the collegiate system to develop international level competitors in the hammer throw, since high school athletes have limited exposure to the event (Connolly, 2006). This makes it extremely important for coaches to make informed decisions of what training factors deserve the most emphasis in the training programme. When learning a highly technical skill like the hammer, repetition and more repetition is the key to success (Dunn and McGill, 1991). Gaining proficiency in motor skills at an early age can put an athlete at an advantage above others who are not practicing their skills as often. If one wishes to truly excel at any given task or skill, he/she must put extensive time, effort, & training into practices that will develop that task or skill. The earlier one chooses to put this effort into a particular area, the more proficient he/she will become (Baker, 2003). Ericsson et al., 1993, reviewed several decades of research studying the effects of practice and training on learning, and suggested that early specialization in any given area was critical to the development of expert status. Collegiate hammer throwers in the United States may not have the opportunity to reach this level of skill development because of their limited opportunities and may have to emphasize strength in order to produce points at a conference or NCAA championship further limiting skill development.

Aside from the teaching and training of necessary technical throwing skills, strength training is the building block of success in the throwing events (Judge, 2007). “Strength” can be defined as a person’s capacity to use muscular activity (enhanced by the use of weights) to exert resistance on external forces in order to overcome these outside forces (Stone et al., 2003a). Strength is
necessary to accelerate a mass and to achieve the desired velocity, impulse, and momentum for success in throwing. Strength has been described by Stone et al., 2003b, as the basis of high level performance in track and field. Why is strength so important in the throws? Stronger athletes are able to hold the positions necessary to master technique. Optimal technique is a set of muscle contractions and relaxations coordinated and synchronized to produce maximum acceleration of the implement (Sale, 2002; Schmidt, 1975). The percentage of strength and power movements in the resistance-training programme may vary based on the stage of training, but strength training should always remain a major element of the training programme (Bartonietz, 1996; Bompa, 1994; Bondarchuk, 1994).

Power is the mechanical quantity that expresses the rate of doing work (Enoka, 1994) and is largely dependent on the ability to exert the highest possible force (i.e., maximum strength) (Schmidtbleicher, 1992; Stone et al., 2003a; Stone et al., 2003b). Numerous studies and review articles have reported evidence and logical arguments for the use of explosive exercises for throwers (Bartonietz, 1996; Judge, 2008; Judge et al., 2008; Stone et al., 2003b). Olympic-style lifts (Clean, Jerk, and Snatch) and their derivatives (Pulls and Shrugs) are the core of the resistance training programme. In addition to the weight lifting exercises, throws, sprint drills, and jumps, the workout contains sport-specific release movements that force core stabilization of high velocity activities (Judge, 2007). Thus, how maximum strength and power are effectively developed are important issues for athletes and hammer throw coaches. Having discussed numerous considerations for improvement in the hammer throw, it is important that coaches prioritize training stimuli. In order for coaches to properly emphasize the key components to training a hammer thrower, it is also imperative that the coaches understand which variables are most essential to hammer throwing success. The purpose of this study was to investigate the training variables that contributed most too maximum throwing distance in the hammer throw event in track and field.

2. Methods

2.1. Instrument
A 41-item survey instrument was developed to collect data regarding national level collegiate hammer throwers throughout the United States. Once completed the questionnaire was sent to a panel of 5 United States of America Track and Field (USATF) Level II certified coaches to assess content and face validity. These professionals after a review of the instrument did not report that any changes were necessary. The questionnaire was subsequently sent to a high school thrower’s club coach that emphasizes the hammer throw for pilot testing. A cover letter, the questionnaire with a specific area for comments, and a self-addressed stamped envelope for returning the questionnaire were sent to twenty-four current high school throwers in Marietta, GA. In a period of one month after the mailing date, the returned questionnaires were reviewed. After analysis for validity and reliability, this review resulted in no major changes being made to the instrument.

The first half of the questionnaire (10 questions) focused on the participant’s personal and athletic information including performance, whereas the second half dealt with technical
questions including the type of technique used by the athlete, injuries and coaching certification of the throws coach at their institution. The questionnaires were distributed via email to the NCAA track and field programmes in the United States and the recipients were asked to return the questionnaire within 7 days of receiving them. Non-responders were mailed a follow-up paper copy of the questionnaire to increase response rate. Of the 212 Questionnaires distributed 74 were returned (34.9% return rate); those surveys represent the subject pool for this study. Upon receiving the completed questionnaires the individual data was coded and entered into an SPSS spreadsheet.

2.2. Subjects
The Institutional Review Board of principle investigator’s university approved this study for the use of human subjects. Each potential participant received an informed consent form that explained the potential risks and benefit of their involvement. They were encouraged to contact the principal investigator of this study to answer any questions or provide clarification prior to giving informed consent. The surveys were mailed to participants who met the initial inclusion criteria of a being a regional qualifier for NCAA Division I, or a provisional national qualifier for NCAA Division II or Division III in the hammer throw event.

2.3. Statistical Analysis
Based upon the prior knowledge of the principal and co-investigators a model to explain the variance in hammer throw performance was created. The five predictors included were: number of throws per year, number of years throwing the hammer, division within the NCAA, back squat 1 repetition maximum and the technique used to throw the hammer. Subsequently multiple linear regression was run in order to explain the variance in hammer throw personal record (PR) distance. Predictors were evaluated for problems of multicollinearity. Some predictors (NCAA Division) were entered into the model for the purposes of controlling known confounding influences, these predictors may not have been individually significant, but remained a vital component of a significant predictive model. Statistical significance was set a priori at alpha<0.05. All statistical analyses were completed with the use of a modern statistics package (SPSS 17.0 for Macintosh).

3. Results
The variables from the questionnaire were analysed for construct validity and internal reliability and demonstrated within group (technical questions, injuries and coaching certification) Cronback's Alpha >0.80 and KMO statistics >0.60, suggesting that the instrument was reliable. Participant characteristics are presented in Table 1. Multiple regression analysis for Hammer Throw PR yielded a significant model (r=0.811, p≤0.001) with the following predictors: number of throws per year, number of years throwing the hammer, NCAA division, back squat, and hammer technique. The model explained in excess of 65% of the variance in hammer technique among the respondents (r²=0.658). The individual predictors in the model were significant except for NCAA Division (β=−0.185, p=0.072), which was included as a control measure. The remaining significant predictors can be seen in Table 2. All significant predictors were
positively associated with hammer personal record (HPR), and the breakdown of the technique can be seen in Figure 1.

Table 1: Participant Characteristics (%, x ±SD)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n=37)</th>
<th>Female (n=37)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yrs Experience Throwing Hammer</td>
<td>3.79±1.69</td>
<td>4.00±1.85</td>
<td>0.619</td>
</tr>
<tr>
<td>Yrs in College</td>
<td></td>
<td></td>
<td>0.749</td>
</tr>
<tr>
<td>Freshman</td>
<td>13.5% (n=5)</td>
<td>10.8% (n=4)</td>
<td></td>
</tr>
<tr>
<td>Sophomore</td>
<td>21.6% (n=8)</td>
<td>24.3% (n=9)</td>
<td></td>
</tr>
<tr>
<td>Junior</td>
<td>16.3% (n=6)</td>
<td>27.1% (n=10)</td>
<td></td>
</tr>
<tr>
<td>Senior</td>
<td>48.6% (n=18)</td>
<td>37.8% (n=14)</td>
<td></td>
</tr>
<tr>
<td>NCAA Div</td>
<td></td>
<td></td>
<td>0.938</td>
</tr>
<tr>
<td>1</td>
<td>78.4% (n=29)</td>
<td>81.1% (n=30)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>13.5% (n=5)</td>
<td>10.8% (n=4)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8.1% (n=3)</td>
<td>8.1% (n=3)</td>
<td></td>
</tr>
<tr>
<td>Hammer PR</td>
<td>59.67±3.61m</td>
<td>58.13±4.87m</td>
<td>0.126</td>
</tr>
<tr>
<td>Throw Hammer in High School</td>
<td>26.30% (n=20)</td>
<td>73.70% (n=56)</td>
<td>0.273</td>
</tr>
<tr>
<td>Number of Throws Per Year</td>
<td>3022.31±1769.42</td>
<td>2963.46±2234.62</td>
<td>0.540</td>
</tr>
</tbody>
</table>

Participant Characteristics given as percentages, or means ± standard deviations. (*) indicates significant difference from male gender. Listed p-values are the result of chi-square analysis for variable by gender. Personal Record (PR) is presented as the best competition effort with the indicated implement.

Table 2: Results of Multiple Linear Regression for Hammer PR

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Beta</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throws per year</td>
<td>0.345</td>
<td>0.002**</td>
</tr>
<tr>
<td>Back Squat</td>
<td>0.325</td>
<td>0.001**</td>
</tr>
<tr>
<td>Hammer Technique</td>
<td>0.263</td>
<td>0.012*</td>
</tr>
<tr>
<td>Years throwing Hammer</td>
<td>0.218</td>
<td>0.025*</td>
</tr>
<tr>
<td>NCAA Division</td>
<td>-0.185</td>
<td>0.072</td>
</tr>
</tbody>
</table>

Results of Multiple Linear Regression for Hammer PR. Results are given in Standardized beta values, (*) indicates significant at p<0.05, (**) indicates p<0.01.
4. Discussion

In order to construct the optimal performance model for the hammer thrower, a training programme must be developed that systematically and progressively builds the proper physiological abilities and necessary fundamental skills that lead to the achievement of peak performance. It is important for coaches to be able to identify and sequence the training effects that contribute to sport form. Number of throws per year and number of years throwing the hammer, back squat and hammer throwing technique were significant predictors of hammer throw distance in the present study. Given that the NCAA reinstated the men’s hammer throw as a championship event in 1959, and added the women’s hammer throw in 1996, the hammer is a relatively new event at the collegiate level, especially for women (NCAA, 2009). The statistics show that most of the throwers in the present study did not have the opportunity to develop their skills at an early age as evidence of their years of experience throwing the hammer; 73.70% had no experience throwing prior to college. In this study, the males averaged 3.79 ± 1.69 years of experience and the females averaged 4.00 ± 1.85. Despite the statistics reflecting inexperience, remarkably a majority (80.30%) of the throwers in the present study felt they had good technique (Table 3).
Table 3: Perceptions of the Hammer Throw by Participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competed in the NCAA National Championships</td>
<td>47.40% (n=36)</td>
<td>52.60% (n=40)</td>
</tr>
<tr>
<td>Think You Have Good Technique</td>
<td>80.30% (n=57)</td>
<td>19.70% (n=14)</td>
</tr>
<tr>
<td>Need to be Strong to Throw Hammer</td>
<td>43.10% (n=31)</td>
<td>56.90% (n=41)</td>
</tr>
<tr>
<td>Are You Strong Enough</td>
<td>66.20% (n=49)</td>
<td>33.80% (n=25)</td>
</tr>
<tr>
<td>Core Strong Enough to Throw Hammer</td>
<td>68.40% (n=52)</td>
<td>31.60% (n=24)</td>
</tr>
</tbody>
</table>

The number of throws per year was a significant predictor of throwing distance in the hammer. When athletes lack youth experience, U.S. collegiate coaches often institute high volume throwing workouts to help athletes gain technical mastery faster. Once acquired, the newly learned hammer throwing skills must be quickly stabilized to prepare for the upcoming competitive season. Stabilization is accomplished with a high volume of throws with varied weight implements. Achieving success in the throws is similar to the pursuit of success in the weight room: a consistent training regime that incorporates a system of overload, progressive resistance, and recovery. According to Bondarchuk, 1994, it is important to change the emphasis of the training programme as the athlete advances. There is a high correlation related to repetitive throws with overweight implements (Bondarchuk, 1994).

The number of years throwing the hammer was another significant predictor of hammer throwing distance in the present study. An athlete with experience in the hammer throw as a youth athlete would have a definite advantage. It is for this reason that many colleges and universities recruit more experienced foreign athletes to throw the hammer (K. McGill, personal communication, June 22, 2009). Gaining proficiency in motor skills at an early age can put an athlete at an advantage above others who are not practicing their skills as often. If one wishes to truly excel at any given task or skill, he/she must put extensive time, effort, & training into practices that will develop that task or skill. The greater the number of years throwing the hammer the more skilled the thrower becomes at mastering the technique. The earlier one chooses to put this effort into a particular area, the more proficient he/she will become (Baker, 2003). Ericsson, et al., 1993, reviewed several decades of research studying the effects of practice and training on learning, and suggested that early specialization in any given area was
critical to the development of expert status. Ericsson et al. (1993), concludes that future expert performers engage in intensive training activities over a period of ten or more years in the cultivation of superior performance. Success, they find, is a function of intensive, deliberative practice conducted while in a state of heightened attention and concentration. Collegiate hammer throwers in the United States may not have the opportunity to reach this level of skill development because of their limited opportunities to master the technique and an over-emphasis on strength in order to produce points at a conference or NCAA championship.

Strength in the squat exercise was a significant predictor of the personal best in the hammer throw for U.S. collegiate hammer throwers. Rotational balance is essential in the hammer throw, along with postural core strength, or spine and trunk stabilization (Connolly, 2009). An athlete with insufficient core strength will bend forward during the throw, which decreases the speed built up in the preparation. According to Stone et al., 2003a, improvement of maximum strength as a result of strength training could improve power and explosiveness and therefore performance in a variety of movements associated with both light and heavy resistances. Building foundational strength with exercises like the squat is a key component to early success in performing hammer drills (Judge, 2008). It is interesting that a large number (43.10%) of the throwers in the present study stated that strength was important to throw the hammer and an even greater number (66.10%) felt they were strong enough to throw the hammer. Further, an even higher number of hammer throwers (68.40%) felt their core was strong enough to throw the hammer. Stone et al. described strength as the basis of high level performance in track and field (2003b). Strength is a necessary component in the throws because it will enable the athletes to hold the technical positions while moving at high velocities (Judge, 2007). In a recent investigation by Nuzzo et al., 2008, it was determined utilizing integrated electromyography (EMG) that muscle activity of the trunk muscles during the back squat exercise is greater or equal to that which is produced during what are considered core training exercises (eg. the stability ball). Therefore, structural multi-joint exercises like the squat lift are recommended for increasing strength and hypertrophy of the core and back extensors (Nuzzo et al., 2008). The Nuzzo et al., 2008, findings from the squat exercise helps explain the high correlation between the 1RM squat and personal best in the hammer throw. The shoulder/hip separation in the catch phrase that creates the torque that accelerates the hammer and the resulting centripetal forces from the hammer at low point are great enough that the athlete must counter the implement by firming up and sitting back against the ball. Both technical skills require the same type of core strength as in the squat (Bartonietz et al., 1997; Dunn and McGill, 1991). The related core strength perceived by the throwers in the present study likely could have resulted from performing the squat exercise. The hammer throwers may not be completely aware of the benefits of the squat on improving strength and ultimately performance in the hammer event.

Although strength has been described by Stone et al. as the basis of high level performance in track and field, (Stone et al., 2006) strength may not be as crucial in a technical event like the hammer throw. According to 1956 gold medalist Harold Connolly, “the positive influence on improved hammer throwing performance from training concentration primarily on acquiring increased strength and power is negligible when contrasted with emphasizing expending greater energy on drills and throwing to acquire high-speed, rhythmical hammer turns” (Connolly, 2009). It is interesting to note, a recent review by Young demonstrated little transfer between
pure strength gains and athletic performance (Young, 2006). In a recent study by Kyriazis et al., 2009, performance in a related rotational throwing event (rotational shot put) was found to be better correlated with muscular power of the lower extremities than with absolute muscular strength at the competition period. Essentially, the association between 1RM squat strength and shot put performance was low and non-significant at any time (Kyriazis et al., 2009). However, Kyriazis et al., 2009, contends, the importance of muscular strength for the development of rotational shot put performance cannot be neglected. According to Kyriazis et al., 2009, “It may be that a certain (yet unknown) level of muscular strength is required as a base for the muscular power to be developed upon (p. 1778).”

Physiological adaptations and skill acquisition occur in multiple areas and are, for the most part, unrelated as demonstrated by Jensen et al. (2005). With little time to fully develop and stabilize their hammer technique, athletes desiring to throw far and farther could be potentially learning bad technical habits by relying on strength which could hinder future technical development and lead to injuries. Considering both the inexperience and bad technical habit development in collegiate hammer throwers, success and mastery of the hammer event within the United States system is very difficult. A potential over-emphasis on strength is reflected by the fact that almost half (48.7%) of the 74 athletes in the present study reported weight lifting injuries. This is alarming considering Watson and DiMartino (1987) found 82% of the injuries that occurred during participation in a track or field activity were in running events and 18% in field events. An understanding of injuries and recovery processes must be part of the coach’s approach to the development and implementation of an athlete’s training programme (Kutsar, 1988). According to Young, combination training or a more balanced approach is necessary to fully develop performance (Young, 2006).

It is interesting that the squat, not the power clean or snatch exercise, was a significant predictor of distance in the hammer throw for U.S. collegiate throwers. Various studies and review articles have reported data and logical arguments for the use of explosive exercises for throwers (Bartonietz, 1996; Judge, 2007; Judge et al., 2008; Kyriazis et al., 2009; Stone et al., 2003b). Olympic-style lifts (Clean, Jerk, and Snatch) and their derivatives (Pulls and Shrugs) are the core of the resistance training programme of strength/power athletes (Judge, 2007; Stone et al., 2003a). Garhammer (1980) reported that snatch and clean and jerk exhibit much greater power outputs compared with squat and dead lift. Numerous investigations (Hoffman et al., 2004; Hori et al., 2008; Stone et al., 1980; Tricoli et al., 2005) have examined the effects of training with weightlifting exercises on the performance of speed and power events. Stone et al., 1980, reported that 14 weeks training with weightlifting exercises enhanced jump performance significantly. Hoffman et al., 2004, compared the effects of 15 weeks of weightlifting exercises versus power lifting (strength) exercises (i.e., squat, bench press, and dead lift) on jumping and sprinting performance, and reported the effectiveness of weightlifting exercises on jumping performance. Tricoli et al., 2005, reported that the improvement in jumping and sprinting performance was superior for a weightlifting group compared with a vertical jump training group after an 8-week training intervention completed 3 times a week. Hori et al., 2009, reported the training of the weightlifting exercises such as the hang power clean may be effective to improve the athlete’s capability of power, and subsequently athletic performance which requires high power for skills such as jumping, sprinting. The results of these studies support the importance of
including explosive lifts in the training programme of athletes in speed and power events like the hammer throw. Research has shown maximum strength and peak power have moderate to high correlations (Stone, 1993). But, Hori et al., 2008, recommends coaches take a holistic approach to training which includes skill practice in addition to development of maximum strength and power.

The type of technique (number of turns) was the final predictor of personal best in the hammer throw. There are two styles being used by hammer throwers today; the 3 turn (three heel turns) and the 4 turn (one toe-turn and three heel turns). The toe turn is a type of turn where the athlete rotates on solely on the ball of the left foot in order to use less space in the ring. The 4 turn (one toe-turn and three heels) had the highest correlation to the longest distance in the hammer throw. Although the men’s world record was accomplished in 1986 with three heel turns, the four-turn technique is the dominant technique employed by advanced male and female throwers worldwide (Connolly, 2009). There is a huge reliance on the collegiate system in the United States to develop competitors in the hammer throw (Connolly, 2009). The first step in learning or becoming a hammer thrower is learning how to rotate, counter and maintain balance. These skills must be learned in four month preparation period prior to the beginning of the U.S. collegiate indoor season. Throwers are first taught to complete a one and two turn throws before moving to a three and four turn technique. Because of the relatively late start in learning the hammer event, U.S. collegiate throwers (18-24 years of age) may be forced to use a two or three turn technique during their first two years of competition. U.S. collegiate coaches are at a disadvantage because of a lack of a feeder system to develop youth athletes in the hammer throw and are forced to introduce two and three turn competitive techniques that may ultimately be disruptive to a four turn rhythm and future technical advancement. Teaching a 4 turn rhythm to athletes is important to keep the body working as a single unit; the head, shoulders, hips, and feet all synchronized moving together with the ball during each successive turn. Teaching a 1 or 2 turn rhythm that is utilized in competition may teach and reinforce bad habits like the “drag” that may difficult to break in the future. Unless high schools nationwide accept the hammer throw in track and field meets, hammer throwing success will remain difficult within the United States.

5. Conclusion

The present results suggest that hammer throw performance depends more on absolute squat strength than muscular power and factors like the number of throws per year, number of years throwing and the type of technique used are important to future success. Thus, besides working to improve absolute squat strength in the weight room, training for maximum hammer throw performance might focus on mastering a four-turn technique and accumulating a high volume of throws over a number of years. Coaches need to take a holistic approach to training which emphasizes the above factors but integrates other important training components like building muscular power, special strength and speed. Results of this study raise some interesting conclusions and suggestions for future research. This paper represents only a modest beginning point for a further more expansive study of the training factors important to success in the hammer throw, but also on discerning quantitative evidence of the critical, most effective
science-based coaching strategies to guide American male and female hammer throwers from adolescence to the Olympic victory stand to achieve their maximum potential.

6. References


Techniques.


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