MUSCULAR POWER (UPPER AND LOWER BODY) AND PERFORMANCE IN THE HAMMER THROW

Submitted by

Meagan K. Cook

A Thesis submitted in Partial

Fulfillment of the Requirements for

The Master of Science Degree

Thesis Chair: Dr. Steven J. Albrechtsen

THE UNIVERSITY OF WISCONSIN-WHITEWATER

August 31, 2006

The University of Wisconsin-Whitewater

Thesis Approved

Meagan K. Cook

August 31, 2006

Thesis Committee

Advisor

ACKNOWLEDGEMENTS AND DEDICATION

This thesis could not have been done without:

Mama, who taught me how to write good
Dad, for always supporting me
Adam M. Cook, for making me go out for track in the first place
Colleen Teska, for your statistical expertise
Dave Hahn, the hammer guru
Jay Wendt, for inspiration
UW-Whitewater throwers, for your skills, support, and friendship
Pat Ebel
Dr. Steven J. Albrechtsen
Dr. Penny Portman
Lee Munger
Dave Wiederrecht
Jeff Newcomer, for helping more than you realize
Richelle Broerman, for your willing involvement and listening to every step along the way

And to God, who gave me the privilege and task to complete this thesis in His Name with the support of those named above, those unnamed, and His wisdom and grace.

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Abstract of Thesis

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ABSTRACT OF THESIS

MUSCULAR POWER (UPPER AND LOWER BODY) AND

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The relationship between upper body power, lower body power, and performance in the hammer throw was studied. At a late season NCAA track and field meet, nine athletes from Division III universities, with at least one year of experience in throwing the hammer, were the subjects for this research. Within one hour after each of the subjects completed all their competitions for the day, including the hammer throw, they performed the standard Wingate test on a Monarch cycle ergometer and a modified Wingate test on a modified cycle ergometer to determine muscular power in both the lower and upper body respectively. Data was then analyzed in Microsoft Excel's spreadsheet and software. A correlational analysis was completed to determine the relationship of the mean differences (within each gender grouping) between performance and PR, performance and R-total (standard and modified Wingate), performance and peak anaerobic power (W/kg) (standard and modified Wingate), and anaerobic capacity (W/kg) (standard and modified Wingate). Statistical levels of significance were determined at the 5% level.

From the women's results, correlations of statistical significance at the 5% level were found with performance and PR (0.977), performance and standard Wingate R-total (0.698), performance and standard Wingate Peak AnC (0.7003), and performance and standard Wingate Rel AnC (0.7666). Correlations were not significant between

performance and all three modified Wingate results: R-total (0.2738), Peak AnC (0.3288), and Rel AnC (0.2875).

From the men's results, correlations of statistical significance at the 5% level were found with performance and PR (0.944), performance and standard Wingate R-total (0.804), performance and standard Wingate Peak AnC (0.6833), performance and standard Wingate Rel AnC (0.7666). The correlation of performance and modified Wingate R-total (0.580) was also statistically significant, but the relationship was weak. Correlations were not significant between performance and the remaining modified Wingate results: Peak AnC (0.4287) and Rel AnC (0.2161).

The correlations between performance and R-total, Rel Peak AnP, and Rel AnC for the standard Wingate, were very strong for both the female and male subjects. The modified Wingate, upper body test, only moderately correlated performance to R-total for the male subjects. This study indicated that the desired power for throwing the hammer related strongly to lower body power. This tends to suggest that lower body power would be a better predictor of current performance, and that future performance would be greatly influenced by training the lower body for higher power outputs.

CHAPTER I

INTRODUCTION

Power and Athletics

In sports, the desire to be bigger, faster, and stronger than your opponent can be more easily understood as having greater power. Power is the rate of doing work (P = force x distance/time) and the product of force and speed (P = force x velocity). In both instances, power is measured in watts (W). Power can be measured as an average over a range of motion or as an instantaneous value occurring over a range of motion under a given set of conditions, peak performance being the highest value in that range (12). Power is then improved by increasing the distance traveled of a mass, body, or object (MBO) in the same amount of time, decreasing the time in the same distance and same MBO, increasing the MBO with the same distance in the same amount of time, or a combination of these variables (14). In other words, power is most greatly influenced by two factors, force output (strength) and speed of movement (velocity – movement in a certain length of time).

Training Power Development

Since strength and speed are important to improving power for athletes, then athletes who participate in anaerobic and explosive-orientated events should be trained to improve in these two fundamental elements. These athletes should participate in training with the goal of developing synchronized actions of the muscle motor units and improving muscular coordination with high-intensity exercises to perform at the highest levels of their sport (13). The three types of exercises that are performed in strength training for power mirror the three ways to increase power as mentioned above:

High force/ low velocity exercises (e.g., back squat)

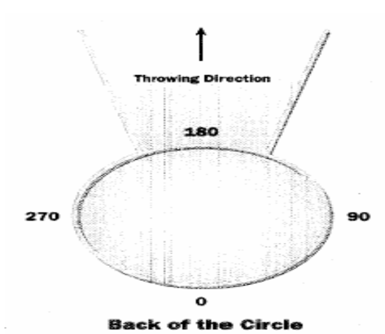
Low force/ high velocity exercises (e.g., light jump squats)

High force/ high velocity exercises (e.g., Olympic lifts)

These exercises train both physiological and cognitive abilities which are believed to make competitors higher quality athletes. By training with these exercises, an athlete will increase their natural power output capabilities which are believed to transfer to the skills and techniques being performed in the sport in which the athlete competes.

The Hammer Throw

Hammer throwing is a dynamic, anaerobic throwing event in track and field. A hammer consists of a metal ball with a swivel with a triangular-shaped handle attached to it through a cable which loops and twines around itself. The men's hammer ball has a diameter of 110 to 128mm, and the total length of the implement measures 1195mm, and the complete implement weighs 7.26kg (16 lbs.) The women's hammer has a diameter of 95 to 102.5mm, a total length of 1177.5mm, and a weight of 4kg (5). (See Figure 2.)



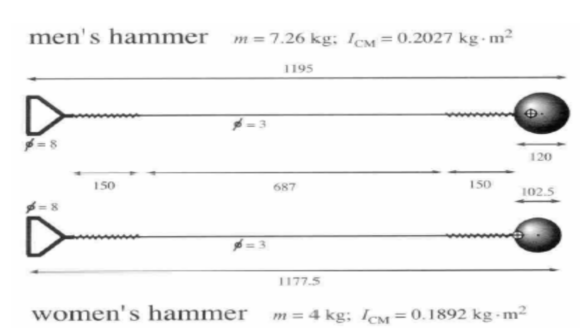


Figure 1 – Circle dimensions (10). Figure 2 – Hammer dimensions (5).

Hammer throwing has been said by former U.S. national-class hammer thrower Greg Gassner to be “paradoxical by nature: a relaxed extension of the arms to create maximum effective radius, (while at the same time) countering the hammer by sitting back against (the force of) the ball. It’s trying to maintain a relatively relaxed, passive upper body with arms fully extended while driving furiously with the lower body and moving the hammer at speeds up to 60 miles per hour” (6).

Training for the Hammer Throw

Because of its limited popularity and research, the hammer throw remains the most misunderstood and ignored event in track and field (10). In the second half of the twentieth century, American hammer throwers receded from the forefront of the event at international competitions, while Eastern European countries have become superpowers of the hammer-throwing world (4). In recent years, several successful American coaches have abandoned the American hammer technique and began to borrow from prestigious Eastern European athletic programs, specifically Russian and Hungarian philosophies, to train their athletes. The demand from coaches for proper training of throwers, especially females, has been growing within the United States, with the women’s hammer still developing as a relatively new event at the collegiate, national, international, and Olympic levels.

The characteristics of throwers under an American philosophy are remarkably obvious to the viewer: an upright posture, a “dragging or pulling” relationship to the hammer, and a general “out of control” manner in the completion of each throw. The dragging or pulling nature comes from the philosophy of the thrower doing the work of moving or “manhandling” the hammer in order to get the furthest distance when thrown. This philosophy, together with the training elements which coincide with teaching this technique, directly opposes the Eastern European philosophy. The differences lie in how the thrower relates to the hammer in order to produce the best throw. As stated, under American technique, the thrower does most of the work of the throw; while under the Eastern European philosophy, the hammer does most of the work while the thrower acts as a function of the natural path of the hammer, accelerating the ball by pushing it (force application.)

Other differences between philosophies, include a much younger age-onset of training of athletes in Eastern European. Eastern European philosophy begins focused training for hammer throwers as young as ten to twelve years old at specialized training schools (9). These schools drill movement development, bodily awareness, and dynamic training during the prime developmental years to build a foundation of fundamentals. Under the Eastern European philosophy, the unity of skill and capacity (strength/power) is the leading principle of strength and technique training for the event at every age to improve the athlete’s ability to resist the force of the hammer pulling away from the athlete throughout the throw (2). Specific emphasis is placed upon training throwers for the development of power through increasing force application. General exercises are suggested to have a negative effect on training result for high level athletes; however, the systematic use of power exercises can develop maximum power and improve speed (16). Weight lifting and power training exercises that mimic the event in characteristics, shape, and specificity provide more than just a strength overload (16,11). Special emphasis is given to develop the “core” (torso area) muscle groups in addition to strength training of other muscle groups, through abdominal exercises, throwing drills, twists, and stabilization exercises.

Tibor Gecsek, Hungarian national record holder in the hammer, listed his weightlifting program as including: the snatch, power cleans, back squats, half squats, leg press and dead lifts (7). At the IAAF Hammer Throw Summit in Szombathely, Hungary, a training video was made demonstrating how their top Hungarian throwers train. All their weightlifting, including snatch and clean high pulls, front squats, and step-ups, was dynamic and rhythmic, performed in sets of three to five reps in conjunction with the number of turns they perform for a throw (9). Pal Nemeth, National Coach with the Hungarian Athletic Association, has his athletes include pull ups as the only primarily upper body exercise in his athletes’ training regiment (9).

Training and Performance in the Hammer Throw

With the heavy emphasis on supplemental training with throwing, it is noteworthy that the national coach for the Hungarian throwers, Nemeth, as well as his top male hammer thrower, Gecsek, attested that their strength and power training consisted almost entirely of whole body or lower body training. Except for pull ups, all the weightlifting exercises are Olympic lifts, lower body exercises, and core training.

Studies of Performance and Characteristics

There have been studies which looked at predicting hammer performance and examined the characteristics of top performance. Both sets of studies have identified training in the afore mentioned areas as crucial to performance (5, 2). Dapena, Gutierrez-

Davila, Soto, & Rojas conducted a study to determine how much the predicted distance of a hammer throw was affected by (1) ignoring air resistance and (2) assuming that the center of mass of the hammer coincides with the center of the ball. Prediction of throw distance was calculated through a mathematical model, formulated from analysis of kinematic conditions of actual throws (men's and women's), used to simulate three-dimensional airborne motion. When using the ball center to calculate center of mass, the predicted distance, in vacuum conditions, was 4.30 $\pm$ 2.64 m (mean $\pm$ SD) longer than the official distance of the throw for men and 8.82 $\pm$ 3.20 m longer for women. However, when using the actual center of mass, the prediction of distance was reduced to a 2.39 $\pm$ 2.58 m discrepancy for men and a 5.28 $\pm$ 2.88 m for women. If air resistance were put back in the equation, for actual center of mass, the discrepancy was further reduced to -0.46 $\pm$ 2.63 m for men and 1.16 $\pm$ 2.31m for women. Total air resistance equally affected both the ball of the hammer and the cable and handle. Calculations from this study were suggested to allow researchers to match actual measured distances in competition to predicted distances based on conditions at release.

In focusing this study upon the affects of air resistance upon performance and center of mass of the hammer, the researchers believed they could reasonably calculate expected performances of throwers. A limitation of this study was that other aspects of preparation, training, equipment, and athleticism affect performance as well. When the researchers were gathering their data from actual male and female throwers, these particular factors were not considered. Also, the three-dimensional analysis from previous research evaluated elite male and female throwers; likewise, any predictor calculations derived from analysis of their throws would be significant for predicting distances of elite hammer throwers. Further analysis would be needed to see if the calculations could be used to predict distances for beginner or lower-level throwers. (5)

Bartonietz, Barclay, and Gathercole presented a biomechanical analysis of Olga Kuzenkova, the leading female hammer thrower at the time of the study, to determine the primary characteristics of her performance. Velocity of release, angle of release, height of release, trajectory of hammer head and hammer positions, and duration of single and double support phases were analyzed in relationship to the distance thrown. Using three dimensional video analysis, the researchers isolated each component from the subject's performance at two international competitions. Based on their findings, the researchers made suggestions for coaches and athletes specific to the training of hammer throwers, such as: the main requirements for training male hammer throwers are also valid for female hammer throwers (increased training quality, optimization of the effects of a year-long training cycle with regard to volume and intensity, and balancing training load with restorative and prophylactic measures); and the unity of skill and capacity is the leading principle of strength and technique training (utilizing the optimal techniques and movement patterns recognized through the analysis and the development event-specific leg power.)

In this study, the researchers suggested that leg power was the crucial element in hammer throwing. Specific exercises were given specific to the development of hammer throwing technique and rhythm. However, in their analysis, the researchers did not analyze any direct relationships between leg power and performance. Hints of the importance of leg power were suggested through the analysis of the support phases, supposing that a longer double support phase related to putting greater force into accelerating the hammer through the turns. If during the analysis of this study, greater durations of force application were again recognized to relate to further distances thrown, then the amount of force or power applied by the lower body could be considered a good predictor of performance. (2)

Purpose of the Study

By developing strength and power in the upper and lower body as well as the core, force can be transmitted from the ground to the hammer. The development of power allows the thrower to apply force into the ground thereby transferring it into the hammer to generate power (8). If the body is the conduit through which force is conducted at the point of impact, then the more efficient the body is at conducting that force (minimizing absorption), the faster an object will be propelled through space and time (8). If, therefore, high intensity resistance training of certain muscle groups plays a vital role in performance in this throwing event, then the power generated within these muscle groups would be an appropriate predictor of throwing performance in this anaerobic event. Based on this, the purpose of this study was to develop a correlative study which evaluated importance of muscular power (upper and lower body) to performance in the hammer throw would benefit both coaches and athletes to evaluate training.

CHAPTER II

METHODS

Subjects

American Division III track and field student-athletes participating in a NCAA late-season track and field meet were invited to participate in this research project. Student-athletes competing in the hammer throw were approached and asked to volunteer for a study of performance in the hammer and upper and lower body power. Testing was conducted after completion of all the subjects' competitions for the day. Subjects were five women and six men who were healthy, college student-athletes who were currently participating in physical activity on a regular basis and who had previously completed a physical examination required for participation in intercollegiate athletics. Subjects also had at least one year of experience, including one competitive outdoor track and field season, in competing in the hammer throw.

Apparatus

Lower body power outputs were measured using a Monarch cycle ergometer. Upper body power outputs measured using a modified Monarch ergometer, with bicycle pedal posts covered with a thin padding layer, placed and secured onto the surface of a table.

Procedures

Each subject's performance in the hammer throw competition was recorded in meters on the official results. Within one hour after completing the all their individual competitions for the day, each subject prepared for testing (1). Prior to testing, the subjects signed informed consent and completed the Physical Activity Readiness Questionnaire (PAR-Q) developed by the Canadian Society of Exercise Physiology with support from Health Canada. Each subject had the testing procedures explained and their PAR-Q reviewed for any problems. Each subject also reported their lifetime personal record (PR) in the hammer throw. Weight in pounds and kilograms was measured for each subject on a digital scale. Weight in kilograms was used to determine the force settings for the standard and modified Wingate tests. Force setting for the standard Wingate test: F = wt(kg) x 0.075. Force setting for the modified Wingate test: F = wt(kg) x 0.025. The prescribed force settings were then rounded to the nearest 0.5 kg to determine the actual force settings. Once the force settings were determined, the subjects adjusted the seat height on the ergometer and completed the standard Wingate test to measure lower body power. After the standard Wingate test, the subject waited at least 15 minutes, but no more than 20 minutes, before performing the modified Wingate test. The subjects were advised to stay on their feet or to walk around during the rest period. The subjects then performed the modified Wingate test to measure upper body power by cranking the covered pedal posts using the upper body. The modified test was otherwise performed in the same manner as the standard 30-second Wingate test .

During both the standard and modified tests, two researchers stood on opposite sides of the subject performing the test and counted foot cycles upon the top of the upstroke during each of the 5-second alternating intervals. A third researcher stood in front of the subject on the ergometer, timed the 30-second tests using a stopwatch, and called out the 5-second intervals. A fourth researcher recorded the revolutions for the intervals on each subject's worksheet and tallied total revolutions after the 30-second tests were completed.

Analysis

After the testing procedures were completed, each subject's peak anaerobic power and total anaerobic capacities were calculated for both the standard (lower body) and modified (upper body) Wingate tests. Data was then analyzed in Microsoft Excel's spreadsheet and software. A correlational analysis was completed to determine the relationship of the mean differences (within each gender grouping) between performance and PR, performance and R-total (standard and modified Wingate), performance and peak anaerobic power (W/kg) (standard and modified Wingate), and anaerobic capacity (W/kg) (standard and modified Wingate). Statistical levels of significance were determined at the 5% level.

CHAPTER III

RESULTS

Table 1 presents the demographic of the nine subjects who participated in this study for both the men and women. Table 2 presents the values for performance, PR, and the standard and modified Wingate test results (total revolutions [R-total,] relative peak anaerobic power [Rel Peak AnP W/kg], and relative anaerobic capacity [Rel AnC W/kg]) for the female subjects. Table 3 presents the results for the male subjects. In each table, the means, standard deviations, and correlations between the subject's performance and their results from the Wingate test are given.

Table 1. Subject Characteristics (mean ± SD)

Characteristic	*Women (n = 5)*	*Men (n = 6)*
Age (years)	21.6 ± 0.8944	21.3 ± 1.633
Weight (kg)	88.12 ± 10.8304	114.88 ± 13.857
Performance (meters)	48.02 ± 7.4997	46.9 ± 7.348
PR (meters)	50.06 ± 6.8496	46.9 ± 7.818

Table 2. Female Subject Results - Standard and Modified Wingate

Women's Results	Perform -ance (m)	PR (m)	Standard Wingate R-total	Standard Wingate Rel Peak AnP (W/kg)	Standard Wingate Rel AnC (W/kg)	Modified Wingate R-total	Modified Wingate Rel Peak AnP (W/kg)	Modified Wingate Rel AnC (W/kg)
Subject # 1	46.41	46.41	43	9.07	6.5	32	1.95	5.74
Subject # 2	36.84	41.16	38	7.23	5.74	48	2.79	6.5
Subject # 3	53.75	54.69	40	9.02	6.02	49	3.22	6.02
Subject # 4	56	58.62	50	10.54	7.32	52	2.93	7.32
Subject # 5	47.08	49.41	42	10.85	6.33	47	2.96	6.33
Mean	48.016	50.058	42.6	9.342	6.382	45.6	2.77	6.382
± SD	7.4997	6.8496	4.5607	1.4446	0.5999	7.8294	0.4840	0.5999
Correlation (Perf & Result)	No data	***0.977**	***0.698**	***0.7003**	***0.6916**	**0.2738**	**0.3288**	**0.2875**

*$p<0.05$

Table 3. Male Subject Results - Standard and Modified Wingate

Men's Results	*Perform -ance (m)*	*PR (m)*	*Standard Wingate* R-total	Rel Peak AnP (W/kg)	Rel AnC (W/kg)	*Modified Wingate* R-total	Rel Peak AnP (W/kg)	Rel AnC (W/kg)
Subject # 1	50.2	56.95	49	13.17	7.17	76	5.27	3.71
Subject # 2	50.35	50.35	49	11.55	7.26	72	4.15	3.55
Subject # 3	39.65	40.43	40	7.11	5.93	49	3.11	2.54
Subject # 4	37.08	40.07	41	6.98	5.96	54	3.93	2.95
Subject # 5	47.33	51.95	54	11.84	8.19	59	4.5	3.16
Subject # 6	56.8	58	51	9.76	7.54	59	3.92	2.57
Mean	46.9	49.63	47.33	10.07	7.01	61.5	4.15	3.08
± SD	7.3482	7.816	5.6095	2.5822	0.8974	10.445	0.7155	0.4884
Correlation (Per & Result)	No data	***0.944**	***0.804**	***0.6833**	***0.7666**	***0.580**	**0.4287**	**0.2161**

*p<0.05

The relative strength of relationships, as cited by Hopkins and Cohen, have been set for meaningfulness of correlation as r = trivial (0.0), small (0.1), moderate (0.3), strong (0.5) very strong (0.7), nearly perfect (0.9), and perfect (1.0) (12). From the women's results, Table 2, correlations of statistical significance at the 5% level were found with performance and PR (0.977), performance and standard Wingate R-total (0.698), performance and standard Wingate Peak AnC (0.7003), and performance and standard Wingate Rel AnC (0.7666). Correlations were not significant between performance and all three modified Wingate results: R-total (0.2738), Peak AnC (0.3288), and Rel AnC (0.2875).

From the men's results, Table 3, correlations of statistical significance at the 5% level were found with performance and PR (0.944), performance and standard Wingate R-total (0.804), performance and standard Wingate Peak AnC (0.6833), performance and standard Wingate Rel AnC (0.7666). The correlation of performance and modified Wingate R-total (0.580) was also statistically significant, but the relationship was weak. Correlations were not significant between performance and the remaining modified Wingate results: Peak AnC (0.4287) and Rel AnC (0.2161).

CHAPTER IV

DISCUSSION

The standard Wingate test has been used by researchers for the purpose of gathering data on the power output of a subject's lower body, while the modified test evaluated upper body power outputs using virtually the same protocol as the standard test. The high power levels represented in the data from the subjects performing the tests suggest that high levels of athleticism and power were needed just in throwing the hammer. Specifically, this study indicated that the desired power for throwing the hammer related strongly to lower body power. As shown in Tables 2 and 3, for both the female and male subjects, the correlations between performance and R-total, Rel Peak AnP, and Rel AnC for the standard Wingate, were very strong. The modified Wingate, upper body test, only moderately correlated performance to R-total for the male subjects. Because the women presented low or no significant correlations among performance and upper body test results and the men only presented one strong and one moderate correlation among the results, it would be suggested that the upper body did not correlate as strongly to performance, as did lower body. This tends to suggest that lower body power would be a better predictor of current performance, and that future performance would be greatly influenced by training the lower body for higher power outputs.

Because the hammer is a dynamic and unpredictable event, there are other factors which may correlate more strongly to performance rather than power. One critical element not tested in this study or mentioned in any of the afore mentioned research is coordination or kinesthetic awareness (5, 2). If the hammer throw is “paradoxical” by nature, with the upper body lengthening and the lower body flexing against the pull of the hammer, the body must be centered not to result in physical damage to the body. An athlete’s coordination and awareness of the body’s sections and whole system is critical to accelerating the hammer through the throw. A study to evaluate the ability of the athlete to balance in extreme or unpredictable positions may also give insight into a new relationship to performance.

The sample size for this study was very small; therefore any of the resulting correlations would only suggest indications related to performance and power for this particular sample. The subjects were also tested when they had individually concluded their competitions for the day. For some of the subjects, they competed in three throwing events and may have felt fairly fatigued at the time of evaluation. One of the women subjects reported that after the test, she was not as tired and thought she could have tested better. Half of the subjects competed in at least one other throwing event, besides the hammer, before performing the test.

The subjects evaluated did report a range of experience and skill level in the hammer throw: two of the subjects, one male and one female, were division III national champions in the hammer. Two of the females and three of the males were All-Americans, all in the hammer except one male in the discus. Two of the males were in their sophomore year and were reported to not consider the hammer their primary throwing event. This was interesting because the range of the years of experience and talent levels were similar for both the female and male subjects, and the results presented similar correlations for each category for both the women and men.

Practical Applications

It is safe to say that every athlete cannot be a world-class thrower. With technique, strength, and power supplemental training along with countless hours of actual throwing repetitions, there still is no magic key to instantly unlock the potential of a beginner thrower to reach world status. It was interesting to notice the different training systems of the subjects in this study. Subjects on both the women's and men's sides were trained under both the traditional American training philosophy and the Eastern European hammer training system. The subjects trained under the Eastern European system produced the highest levels for R-total, Rel Peak AnP, and Rel AnC for lower body power, as well as recording the top three performances for the women and top four performances for the men.

The results of this study suggest training hammer throwers to improve performance would rely upon their development of lower body power. In the United States specifically, the training of athletes has generalized to improving overall strength and power throughout all their muscle systems. Weight training programs for throwers have especially focused on improving upper body power, conceivably because of the "throwing" action. However, if these results are valid, then weight training and power programs should develop a higher level of lower body power proportionate to the development of upper body power. The results of this study would also support the training regiments of Eastern European countries, such as those described earlier, which almost exclusively train the whole body (Olympic lifts, high pulls, and rhythmic lifts), lower body (various squats, leg presses, and dead lifts), and the core (abdominal, stability, medicine ball exercises, etc.)

Besides weight training, the training of hammer throwers should include general conditioning and hammer-specific dynamic training. The conditioning of the hammer thrower should again reflect an unbalanced development of power emphasizing the lower body and core in relation to the upper body. Coaches would be wise to use the training systems of conditioning and plyometrics originated used by the Eastern European countries, to emphasize and develop lower body power more than upper body power to most effectively train their athletes for success (2, 9).

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