An analysis of performance evaluation criteria for hammer throwers: A case study of Olympians

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[Abstract]

The objectives of the present study were to consider and examine variables valuable for hammer throwers when preparing and conditioning for the Olympic Games. In order to do so, results and data from the past 4 Olympic Games (2000–2012) and pre-Olympic competitions were collected to determine individual means (AVG) and standard deviations (SD) for the pre-Olympic competition records, season best record (SB), and achievement rates (OG/SB) for Olympic game (OG) results. The differences between each relationship and the OG for each year were examined for the categories evaluated.

1) Although it was suggested that -4% from a Personal best record (PB) and/or SB are the Top Condition for a throwing event, the mean value of OG/SB for the top men/women finalists was significantly higher and exceeded the top condition value.
2) In comparing the results of PB, SB, pre-Olympic competition records, and each individual's top 3 individual means and/or standard deviations for pre-Olympic competitions, a moderate positive correlation was observed for both men and women in the following order: pre-competition AVG>TOP 3 AVG>SB>PB.

Because a strong association between the pre-competition individual means and the OG was observed, it has been suggested that improving pre-competition AVG, as well as aiming for high PB and SB, may lead to favorable and positive results at the Olympic Games. Furthermore, compared to other indicators, PB had less relevance to the OG, so it can be considered that as a performance evaluation method, other than making a comparison with an PB, combining the -4% records for the SB and the actual SB would be the best way to evaluate performance in preparing for the competitions.

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オリンピック・ハンマー投選手におけるパフォーマンス評価基準に関する研究

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［要 旨］

本研究の目的は，陸上競技ハンマー投選手が，オリンピックに向けて準備・調整を行う過程において有用なパフォーマンスの評価指標について検討することである．そのために，オリンピック 4 大会（2000－2012 年）とオリンピック本番までに出場した当該シーズンの競技会（事前競技会）におけるリザルトデータを収集した．オリンピックの記録（OG）とシーズンベスト（SB）に対する達成率（OG/SB），事前競技会記録の個人内平均値(AVG)と標準偏差(SD)を求めた．これらの評価項目間の関係性ならびに，オリンピックの成績との関連性を検証した．

1）投擲競技では，PB や SB を基準に-4%までの記録をトップコンディションと評価すべきと提案されている．男女ともに決勝進出した上位群は下位群に対して，OG/SB の平均値が有意に高く，トップコンディション値を超えていた．

2）OG に対する PB，SB，事前競技会記録と事前競技会トップ 3 記録(TOP3)の各 AVG および SD の相関分析の結果，男女ともに、事前競技会 AVG＞TOP3AVG＞SB＞PB，の順に中等度以上の正の相関が認められた．

以上より，事前競技会 AVG と OG との間にもっとも強い関連性が認められたことから， PB や SB を目指すことのみならず，事前競技会 AVG を高めるよう努めることが，オリンピックでの好ましい結果につながりうることが示唆された．更に，PB は他の指標より OG との関連が低かったことから，PB との対比以外のパフォーマンス評価方法として，SB ならびに SB に対する-4%記録を併用することが，準備過程におけるパフォーマンスの適正評価という点において有用であると考えられる．

Ⅰ Introduction

1. History of hammer throw in Olympic Games

The men's hammer throw has been an official Olympic event since the Paris Games in 1900. The women's hammer throw, however, only became an official event 100 years later, at the Sydney Games in 2000. Therefore, it has only been performed four times, the most recent competition being at the London Games in 2012. The men's World Record has not been broken since 1986, while the women's World Record has been improved upon nine times up until 2015 since the 2000 Sydney (iaaf.org, Hammer throw). Since the women's hammer throw has such a short history, consistent improvements in records at international level may be presumed and women hammer throwers need to consciously and constantly develop and improve their records for the future.

The thrower usually makes three or four spins before releasing the hammer (Murofushi, 1994) and attempts to land it inside a 34.92°-wide sector *1 , competing against other athletes to throw the hammer the farthest distance (iaaf.org, Rules & Regulations). It is believed that the throwing distance is determined by the instant of release (Sakurai, 2004).

2. Rules for the Olympic qualification in hammer throw

To qualify for the Olympic Games, it is necessary to fulfill the qualification requirements set by the IAAF (International Athletics Federation).

These are as follows: (1) surpass a certain qualifying mark within the designated three throws; (2) rank in the top 12 candidates. The final, which is held on a different day, begins with each thrower making three throws each, and each athlete's longest throw is recorded. Then, the eight athletes who have thrown the farthest receive three more throws. In this round, the longest single throw wins. Even if each athlete, who are at different competition levels, have different steps and strategies to qualify for each level of competition, there is no doubt that each participant will strive to accomplish their best possible performance.

3. Performance indices of track and field events

Muraki (1989, 1994) analyzed all of the track and field participants from two separate Olympic Games in order to determine the renewal rates of their records (i.e., their ability to replicate or improve upon their personal bests). From these results, it was found that the probability of improving upon a personal best record is approximately 35% for track events, 20% for jumping events, and 10% for throwing events. Since it is possible to evaluate performance as a common indicator for track events and the

marathon but, for field events, each discipline has a noticeable characteristic difference, so each discipline requires an appropriate evaluation index. In regard to the hammer throw, the degree of difficulty to perform at the best level is higher and it is considered a difficult event for which to condition and train. *2

4. Peaking and conditioning for the major competitions

In order to perform at their highest level, the athlete must adjust the periods at which they peak during their conditioning process. To successfully peak at the right times, they will also condition and train for pre-Olympic competitions. The peaking process is based on a repetitive cycle of changes in conditioning, however, even if the conditioning is based on a training program, it does not guarantee good results at competition (Muraki, 1994). Matveyev (1964) stated that only 15–25% of track and field athletes achieve their season best record (SB) at large-scale competitions such as the Olympics and World Championships. Considering the difficulty of improving records in throwing events, it can be said that the probability of a hammer thrower achieving a personal best at the Olympics is considerably low. Since producing a personal best at a targeted competition is difficult (Suslov, 2010; Aoyama, 2013), and peaking is especially difficult, this means that this is an important issue for hammer throwers that can affect Olympic results. Therefore, it can be surmised that SB and pre-Olympic Games competition results affect Olympic results. If this relationship can be better clarified, it may provide clues to finding accurate peaking methods that accommodate the characteristics of the hammer throw.

To achieve peak performance at important competitions, planned training programs designed for peaking at particular times have been implemented and their effectiveness has been clearly demonstrated (Matveyev, 1964; Gamble, 2006; Bompa & Haff, 2009; Issurin, 2010; Suslov, 2010; Turner, 2011; Aoyama, 2013).

5. Producing Top Conditions

For a process by which appropriate training is conducted to enhance performance that, in turn, results in athletic development, Matveyev (1964) defines the highest state obtained for each stage of development as the “Top Condition” (Muraki, 1994). To determine the standard criteria for achieving Top Condition in track and field events, a value of up to -2% of the athlete’s personal best or SB has been suggested. However, because this standard value is mainly based on track events, a study has been conducted on values that match the criteria for the characteristics of each athletic event (Muraki, 1998; Fujikawa, 2007; Sakuma, 2007). For throwing events, it has been proposed that a standard value be set for best results obtained during a training period

and SB at competition, and that -4% from these results be set as the Top Condition (Muraki, 1987, 1989). In order to break a personal best record, an essential goal is to comparatively evaluate that record. For athletes who are still young and can be expected for further growth, there is a higher possibility for them to break their own personal best. On the other hand, for veteran athletes, their personal best record is far from their present level so there is a need to take into account that a comparative evaluation may not be adequate evaluation for comparison.

It has been estimated that producing a Top Condition performance that is close to a season best can only be achieved between one and three times per year and such as performance is, therefore, difficult to repeat numerous times within a single season (Suslov, 2001). However, there have been reports that top athletes in field events have produced Top Condition records on numerous occasions during a season (Issurin, 2010). Using such examples of top-class athletes to research their abilities to perform at Top Condition at the Olympic Games, it is necessary to research the importance of not just improving the SB, which is an athlete's estimated competition level, but also to achieve and stabilize Top Condition results at pre-Olympic competitions. However, in the hammer throw, no known research has been conducted specifically on the relationship between Olympic results, SB, and pre-Olympic competition records.

In order to exhibit peak performance at the Olympics and to finish in the top group, it is necessary for an athlete competing in the hammer throw to produce a throwing record that is close to a PB and/or SB. To realize this, one of the conditions for the thrower is that they must stabilize their pre-Olympic competition records at a high level.

6. Purpose of the study

The objective of this research is to consider what the most valuable evaluation indicator is for a hammer thrower when preparing and training for the Olympics. This research is composed of three phases. In Study 1, in order to obtain basic information on the men's and women's hammer throw, the results from the past four Olympics, Sydney 2000 to London 2012, are analyzed and the degree of maturity of the competition over time is examined. Study 2 analyzes the relationship between an achievement rate of -4% SD, which is considered Top Condition, Olympic results, and approximate and renewal rates of Olympic results in relation to SB. Then, the influence of this relationship on Olympic results achievement levels is examined. In Study 3, the relationship between Olympic results and SBs, which are proximate to Olympic results and Personal best record, Mean Values (AVG) and Standard Deviations (SD) of results from pre-Olympic competitions, are analyzed and their effects on the level on pre-

Olympic competition records and their stability with Olympic achievement levels is examined.

Ⅱ Study 1: Analysis of trends in the level of competition in men's and women's hammer throw at past four Olympic Games.

1 Method

(1) Analytic Items

1) Qualifying standard record: Standards A and B must be met for eligibility to participate in the Olympic Games
2) Qualifying record (cut-off point): The qualifying standard for each Olympic Games
3) Qualifying round record: An athlete's highest performance at a qualifying round for the Olympic Games
4) Final round record: An athlete's highest performance at the final round of the Olympic Games
5) Olympic Games result (OG): For all athletes who advanced to the finals, this is their best performance at those finals. For all athletes who did not advance to the finals, this is their best performance in the qualifying round
6) SB: An athlete's best performance at any competition prior to the Olympics in an Olympic year

(2) Data Processing

The total number of participants from all four Olympic Games was 151 men and 163 women. Of these, the following were excluded from the analysis: disqualified for doping violations: 2 men; 1 woman; No Mark (athletes who failed to take part): 9 men (9 qualified), 9 women (1 finalist, 8 qualified); Outlier testing: 1 woman (qualified) whose OG was significantly lower than her SB [It should be noted that based on the excluded woman's OG, the outlier value was confirmed by an outliers value test using interquartile range (IQR)]. Therefore, the total number of participants analyzed was 142 men and 152 women. For those who participated in multiple Olympic Games, their data were handled independently per game. Duplicative number for more than 2 Games was, 38 Men (2 Games: n=18, 3 Games: n=13, 4Games:n=7), and 48 Women (2 Games=37, 3Games: n=10, 4 Games: n=1). The target numbers for each game were as follows: Sydney: Men, n = 43, Women. n = 26; Athens: Men, n = 31, Women, n = 45; Beijing: Men, n = 30, Women, n = 45; London: Men, n = 38, Women, n = 34.

Each competition's qualifying round records, final round records, and OG average median values were calculated.

(3) Statistical Analysis

An independent sample test was performed to determine if there was a significant difference between the OG data from the four Games. In doing so, the study was unable to postulate homoscedasticity (equal variance) for the four games, so the Kruskal-Wallis H Test was used to test for non-parametric. If significance was confirmed for the median value, it was subjected to the Mann-Whiteny U Test with Bonferroni corrections for multiple comparisons. The significance level for all tests was set to no less than 5%. For statistical analysis, the SPSS Statistics 18 software program was used.

2 Results

Tables 1 and 2 show the Olympic participation standard record, qualifying record for final, qualification round, final round, and the overall results (median value). For the men, no difference was found between the competitions in any of the fields and, in all four Olympic Games, the records remained stable and no particular change was observed. On the other hand, the women's records showed an increase in all areas in each successive Olympic Games. Additionally, the men's qualifying standard record was set to the same level as the participation standard record A, but the women's standards were set higher the participation standard record A.

Table 1. Median value of the men's participation standard, qualifying record for final, qualification round, final round, and overall results from the past four Olympic Games. (unit = m).

Olympic Games Men's event (N = 142)		Sydney	Athens	Beijing	London
Olympic participation standard	A	75.50	78.65	78.50	78.00
	B	72.20	74.35	74.00	74.00
Qualifying record for Final	Pre-set	77.50	78.00	78.00	78.00
	Rank 12	76.61	76.69	75.34	74.69
Qualification round	Under rank 13 median	71.90	73.54	72.19	71.95
	N	31	21	18	26
Final round	Gold	80.02	82.91	82.02	82.28
	Rank 8	77.32	76.22	78.65	76.07
	Finalists median	77.94	78.05	79.57	77.14
	N	12	10	12	12
Overall results	Median	74.22	75.08	74.46	72.86
	N	43	31	30	38

Table 2. Median value of the women's participation standard, qualifying record for final, qualification

round, final round, and overall results from the past four Olympic Games. (unit = m).

Olympic Games Women's event (N = 152)		Sydney	Athens	Beijing	London
Olympic participation standard	A	65.00	67.50	69.50	71.50
	B	63.50	64.00	67.00	69.00
Qualifying record for Final	Pre-set	65.50	68.50	71.50	73.00
	Rank 12	63.29	68.27	69.36	70.48
Qualification round	Under rank 13 median	60.20	64.99	66.29	67.58
	N	14	34	35	23
Final round	Gold	71.16	75.02	76.34	78.18
	Rank 8	66.15	70.40	71.00	73.06
	Finalists median	66.94	72.15	71.56	74.60
	N	12	12	11	11
Overall results	Median	62.12	65.91	67.32	68.51
	N	26	46	46	34

After using the Kruskal-Wallis H Test to find the difference in average value between all of the Olympic Games events, the results were as follows: Men: no significant difference was observed for each of the games (x^2(3, 142) = 7.61, p = 0.055); Women: Significant differences were observed (x^2(3, 152) = 30.95, p = 0.000). Following performance of a multiple comparison test, the results from Sydney were found to be significantly lower than those of Athens (p = 0.008), Beijing (p = 0.001), and London (p = 0.000). Moreover, the results from London were found to be significantly higher than those of Athens (p = 0.000) and Beijing (p = 0.005). No significant differences were found between Athens and Beijing.

Ⅲ Study 2: Analysis of relationship between OG and SB and/or pre-competition results

1 Method

(1) Analysis Category

1) SB renewal rate: the percentage of athletes whose OG performance was an improvement on their SB
2) Achievement level (OG/SB): OG achievement rate compared to SB (OG/SB × 100 - 100)
3) Pre-Olympic competition results (Overall, Top 3): Individual M and SD results from pre-Olympic competitions (participants in three or more pre-Olympic competitions)
   ① Overall: All targeted pre-Olympic competition results.
   ② Top 3: Since Top Condition can be achieved one to three times a year (Suslov, 2001), the top three SB from the pre-competition results were analyzed.

(2) Data Processing

The top 12 men's and women's finalists at several competitions were grouped as follows: Top finalist group (TFG) (medalists); Middle finalist group (MFG) (ranked 4th to 8th); Bottom finalist group (BFG) (ranked 9th to 12th); and Non-qualifier group (NQG) (those ranked under 13th place who did not qualify). From these groups, 134 men (TFG: 9; MFG: 20; BFG: 14, NQG: 91) and 151 women (TFG: 12; MFG: 20; BFG: 14, NQG: 105) who competed in pre-Olympic competitions were analyzed. Then, both the men and women were separated into four groups to calculate the M and SD. To determine the number of athletes who participated in pre-Olympic competitions, the average number of all athletes in all four groups shows calculated.

(3) Statistical Analysis

First, using an unpaired one-way ANOVA analysis of variance, the average values from two categories (Overall and Top 3) in SB, OG, OG/SB, and pre-competition results were verified (assayed) to find the difference between the four groups. If a significant effect was observed through the variance analysis, a multiple comparison test was conducted. Since the sample size of each group was different, the Hochberg method was used for the multiple comparison tests.

The frequency data was classified in a 2 × 2 contingency table for the two groups classified by Olympic rankings and the existing or non-existing renewal rate based on the SB renewal rates (TFG + MFG, BFG + NQG). However, as there were numbers under 5 in the expected value, Fisher's exact test was used to test the differences between the two groups for both men and women.

(4) Results

Tables 3 and 4 show the average values for the four groups and the M and SD for the pre-competition participation numbers, OG, SB, OG/SB, and the two items (Overall and Top 3) for pre-competition results. The M from each factor was verified to find the difference between the four groups using an unpaired one-way ANOVA of variance.

Table 3. Mean Value (M) and SD for the four men's groups' OG, SB OG/SB, and the two pre-competition results categories (Overall and Top 3) (units = m).

					Pre-Olympic competition results			
Group	Competition frequency	OG	SB	OG/SB (%)	Overall M	SD	Top 3 M	SD
TFG	6.6	80.32	81.42	-1.3	78.86	1.69	80.32	0.81
MFG	10.9	78.21	80.05	-2.3	77.35	1.85	79.23	0.67
BFG	8.7	74.87	78.80	-5	76.36	1.63	77.93	0.58
NQG	8.8	72.63	77.90	-6.7	75.07	1.89	76.84	0.88

For SB, OG, and OG/SB, significant differences were found as of TFG>MFG>BFG>NQG in subsequent tests. For overall M and top3, TFG>BFG>NQG and MFG>NQG were found to be significant.

Table 4. Mean Value (M) and SD for the four women's groups' OG, SB OG/SB, and the two pre-competition results categories (Overall and Top 3) (units = m).

					Pre-Olympic competition results			
Group	Competition frequency	OG	SB	OG/SB (%)	Overall M	SD	Top 3 M	SD
TFG	9.7	74.21	74.72	-0.6	71.71	2.27	73.92	0.63
MFG	9.2	71.54	72.92	-1.8	69.87	2.09	71.88	0.87
BFG	9.9	67.62	70.69	-4.3	67.47	2.27	69.69	0.82
NQG	10.1	64.73	69.73	-7.2	66.37	2.34	68.64	0.83

For SB, OG/SB, overall M, and top3, significant differences were found as of TFG>BFG>NQG and MFG>NQG in subsequent tests. For OG, TFG>MFG>BFG>NQG was found to be significant.

First, in relation to the men's SBs, significant effectiveness was observed (F (3,130) = 13.091, p = 0.000). In the following tests, the relationship, TFG > MFG > BFG > NQG, proved significant. For the women, the same effectiveness was also observed (F (3,147) = 14.275, p = 0.000). Following that test, the relationship TFG > BFG > NQG and MFG > NQG proved most effective.

For the OG, significant effectiveness was observed in relation to the men (F (3, 130) = 71.024, p = 0.000) and the post test results proved TFG > MFG > BFG > NQG to be effective. For the women, the same significant effectiveness was observed (F (3,147) = 42.881, p = 0.000, and the post-tests also proved TFG > MFG > BFG > NQG to be effective.

For the OG/SB, a significant effect was observed in relation to the men (F (3,130) = 27.053, p = 0.000). In subsequent tests, the relationship TFG > MFG > BFG > NQG was effective. For the women, the same significant effect was also observed (F (3,147) = 24.632, p = 0.000). In subsequent tests, the relationships TFG > BFG > NQG and MFG > NQG also proved to be effective. No significant difference was observed between TFG and MFG for either men or women, and both groups achieved a determination reference

value of -4%, which is the Top Condition for throwing events. However, the average BFG and NQG values did not exceed the determination reference value.

For the mean value of the Overall category, a significant effect was observed for the men (F (3,130) = 17, p = 0.000). In subsequent tests, the relationships TFG > BFG > NQG and MFG > NQG were found to be significant. A significant effect was also observed for the women (F (3,147) = 16.096, p = 0.000). In subsequent tests, the relationship TFG > BFG > NQG and MFG > NQG was significant. No significant difference between TFG and MFG was observed for either men or women. As regards the Overall category results, no significant effects were observed for either men or women.

For the mean of the Top 3 category, significant effect was observed for the men F (3,130) = 13.823, p = .001). In subsequent tests, the relationships TFG > BFG > NQG and MFG > NQG were significant. A significant effect for (F (3,147) = 16.096, p = 0.000) was also found to be effective for the women. In subsequent tests, the relationships TFG > BFG > NQG and MFG > NQG were significant. No significant difference was observed for either men or women between TFG and MFG. As regards the SD of the Top 3, no significant effects were observed for either men or women.

The SB renewal rate for men was 4.9% (7 of 142 participants). By group, that of the TFG was 3.5% (5 of 12), MFG was 1.4% (2 of 20), and those of the BFG and NQG were 0%. For the women, the SB renewal rate was 7.9% (12 of 152 participants). By group, that of the TFG was 3.3% (5 of 12), MFG was 2.6% (4 of 20), BFG was 0.7% (1 of 14), and NQG was 0.7% (1 of 106).

The Fisher's Exact Test, which was performed to test the two groups with/without renewal (TFG + MFG, BFG + NQG) and the frequency of the 2 × 2 contingency table showed that both men and women who ranked in the top group (TFG + MFG) had higher renewal rates than the athletes in the lower groups (BFG + NQG). Men: x^2 (1) = 25.310, p = 0.000, women: x^2 (1) = 26.344, p = 0.000）

Ⅳ **Study 3: Relationship analysis of consistency in pre-Olympic Games competitions and Olympic results**

1. Method

The PB (An athlete's Personal best record prior to the each Olympics), SB and two items concerning pre-Olympic Games competition results relating to the OG were analyzed by gender for correlation. The items that were analyzed were the same as those in study 2, i.e., athletes who had participated in three or more competitions. As the sizes of each group differed, Pearson's rank correlation coefficient was used and

the significance level was set to less than 5%.

2. Results

The correlation results are shown in Tables 5 and 6. For both men and women, there were strong relevance to high pre-competition average (r = 0.762, r = 0.836), and the results confirmed that more than moderate to positive correlation was observed for the top 3 average in the following order (r = 0.715, r = 0.824), SB(r = 0.664, r = 0.802), PB(r = 0.635, r = 0.799). Also, only the men's results showed that there was a weak negative correlation between the top 3SD and OG (r = -0.279, p<.01).

Table 5. Correlation between the men's PB, SB and two pre-Olympic Games competitions results against the OG.

TFG=9 MFG=20 BFG=14 QG=91	PB	SB	overall		top 3 records	
			mean	SD	mean	SD
OG	.635**	.664**	.762**	-.142	.715**	-.279**

Note. r: Pearson correlation coefficient.
Correlation is significant (* $p < 0.05$; ** $p < 0.01$).

Table 6. Correlation between the women's PB, SB and three pre-Olympic Games competitions results against the OG.

TFG=12 MFG=20 BFG=14 QG=105	PB	SB	overall		top 3 records	
			mean	SD	mean	SD
OG	.799**	.802**	.836**	.040	.824**	-.076

Note. r: Pearson correlation coefficient.
Correlation is significant (* $p < 0.05$; ** $p < 0.01$).

Ⅴ **Discussion**

1) Changes in hammer throw performance level at the Olympics

In Study 1, the transition of competition level was estimated by analyzing changes in each result from the past four Olympic Games for both men and women. For the men, no significant difference was observed between the four sets of Games, and the results remained stable. For the women, an increase in the OG, final round, and qualifying round results from the 2000 Sydney Games to the 2012 London Games was observed. In particular, an obvious improvement was evident between the Sydney and Athens Games and the Beijing and London Games.

Since the men's hammer throw has a long history at the Olympics, it is considered

to have developed more. However, as it was first introduced at the Sydney Games, the women's hammer throw has a shorter history, therefore, a quicker improvement in record can be expected due to consistent improvements in the OG. In the future, the rate of increase in the records will become more gradual as the record range of throwers who have advanced to the finals narrow. It can be said that it is necessary that women constantly set goals with the estimation that the competition level will be higher in the coming Olympic Games.

2) Relationship between achievement levels and performance at the Olympics

In Study 2, the competitors were divided into four different groups according to their Olympic results. Then, the SB renewal rate was calculated based on each competitor's SB renewal rate percentage. In addition, to determine the Top Condition values, the achievement rate for OG compared to SB (OG/SB) was calculated. As a result, it was found that both genders had low rates, as the SB renewal rates for men and women were 4.9% and 7.9% for all participants, respectively. Additionally, the TFG and MFG categories, which include both male and female winners, clearly showed a higher renewal rate than the other two groups, which did not include any winners. In addition, no significant difference was found in the OG/SB for both the men/women's TFG and MFG, but a clear difference was observed between these two groups and the BFG and NQG. The group featuring the winners was capable of demonstrating a higher achievement level in the SBs than the groups that did not include any winners.

To rank highly in a competition, it is important to not only raise one's competitiveness as estimated by the SB, but also to achieve and produce higher record close to the SB. At an important competition such as the Olympics, both men and women have shown trends that conform to this hypothesis. In addition, the SB renewal rate is 15–25% (Matveyev, 1964) in relation to SBs at important and large competitions, however, at the actual hammer throw event in the Olympics, the values for both men and women were found to be lower. It is considered to be a difficult task for hammer throwers to produce their best performance at important competitions.

3) Relationship between achievement levels and pre-Olympic Games competitions results at the Olympics

In the Olympic hammer throw event, it was found that not only is the level of competition as estimated by SBs, strongly influential, but also the achievement level estimated by the OG achievement rate for SB. In other words, this suggests the importance of peaking and conditioning. An examination of the relationship between the results of pre-Olympic competitions and the Olympic Games showed that the

higher-ranked athletes in the Olympic Games were able to prove the high level performance at the previous consecutive competitions in a respective season which presumably reflects their ability to produce Top Condition prior to the most important events at the Olympics.

The top condition criterion of -4% which was proposed by Muraki (1987, 1989) for throwing events was achieved for both men and women in the OG/SB average for TFG and MFG. This is suggested to be a valid standard in predicting hammer throw performances in important competitions such as the Olympics. Therefore, in order to peak at important competitions when aiming for a PB and/or SB, the competitor can set an adjustment goal that exceeds the Top Condition value of -4%, so that there is a possibility of performance enhancement.

In Study 3, a correlation analysis for OG, compared to PB, SB and pre-Olympic Games competition results was conducted. A relatively strong association between 2 items in pre-competition results and Olympic results was found for both men and women, and followed by, in order, SB and PB. There were more than moderate correlations between PB but this was a weaker value when comparing it to SB and average values. From this, to achieve PB or SB, the competitor should try to raise the pre-competition results and top 3 results as much as possible for it is considered effective in preparing to perform well at the Olympics.

For men, since there was a low negative correlation for the Top 3 SD in pre-competition events, this can be presumed to be a factor that leads to achieving Top Condition at the Olympics. Hence, in order to peak at the Olympics and achieve Top Condition, the competitor should aim to stabilize their performance and reduce fluctuations not only at pre-competition events, but also at other competitions and, consequently, to achieve higher results. This is an important element in the men's event, which is more developed.

For the women, no significant correlation for the SD for pre-Olympic Games competition results was observed. Unlike the men, the clear improvement in overall results of women's event at the last four Olympic Games have been shown. Therefore, female athletes should constantly aim for throwing PB and/or SB in the process of conditioning, rather than minimizing the fluctuation range at a series of pre-Olympic Games events, which may lead them to peaking to the best condition and performance at the Olympic Games. It is important to produce better results, on average, high results in all pre-Olympic Games competition events and to aim to stabilize results with little fluctuation; this will presumably lead to achievement of Top Condition.

The same performance evaluation of comparative evaluation of PB is the common for both men and women hammer throwers, although, it is not easy to actually achieve a

PB. There are many male veteran hammer throwers who have experienced the Olympic Games a few times so that depending on the level of the competitor, there is a possibility that there are differences in the goal and conditioning methods. By implementing performance assessment methods through conditioning to meet current ability SB, and making a personal evaluation by appropriately using the -4% reference value for PB and SB, the athlete can be properly evaluated at their current level and it may also be effective in finding evaluation and modification points. In conjunction with the evaluation, by providing an adjustable goal value with a guide to evaluation records, it is considered that it can be a useful conditioning method for increasing ability. Competition records are considered to be important elements in measuring the effectiveness of peaking and can be influenced by daily training and conditioning. The findings of this study suggest that the inclusion of Top Condition assessment methods and adjusted goal values in everyday training can be considered to be a valid performance enhancement technique for the hammer throw.

It must be noted that this study focused on analyzing competition results and was not intended to study performance from experimentally obtained data. Therefore, results obtained from this study should set the directionality as follows: 1) Adjust goal values to more than -4% from the SB, as suggested in this research; 2) The same survey methods should be used to confirm if the efficacy suggested in this study holds true for other throwing events. In other words, whether they obtained knowledge is limited to the hammer throw or if it can also be adapted for other throwing events; 3) The results of this study and future ones may likely recommend a more effective conditioning method for athletics events that require more difficult and advanced skills such as the hammer throw. For example, in order to consistently set high records at pre-competitions, it is important to conduct regular throwing practice in a competition-like format and increase the ability to replicate the best performances achieved in daily training in competitions. It is also important to explore a peaking method for achieving peak performance and empirically clarify its effectiveness.

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Commentary

*1 Up until the 2000 Sydney games this sector was 40° degrees wide

*2 As a supplemental reference, it is difficult to differentiate conditioning and training, but each has its own concepts and definitions (Johnson, 1971). This research defines training as an element of motor behavior that is conducted for the direct improvement of expertise and ability in the hammer throw. On the other hand, conditioning includes training and has broader implications, such as adjusting and performing physical, psychological and physiological elements to create a process that promotes improvement of physiological functions.

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