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# Heptathlon: The Current Scoring System and its Biases: An Analysis into the Distribution of Scores

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*Heptathlon is an Olympic combined event including seven track and field events. It is intended to identify the most versatile athlete. Performances from each event are scored using a points system and then summed up to reach a final score. The objective of this study is to examine if the data distribution of the heptathlon scoring system equally represents the seven events and to explore the contribution of each event to the final score. To determine this, a multiple linear regression was conducted on the results of 433 heptathlons from 19 competitions. The results showed that the scores among the disciplines are unequally distributed with throwing events having the smallest proportion (12%) and hurdles having the greatest proportion (17%) on the final score. Track events show, on average, smaller standard deviations (940.06±67.95) in their scores in comparison to field events (836.90±88.62). Long jump seems to be a key predictor for an athlete's final score (B=118.33). Concluding, the current scoring system is not well suited to determine a multitalented athlete. It favors sprinters and jumpers over throwers and should therefore be reconsidered. Further research is necessary to develop a system that treats all events equally.*

**Keywords:** *combined events, scoring system, performance analysis, heptathlon, IAAF*

## Introduction

### *Mathematical Background*

Nowadays, combined events are part of the track and field events in the Olympic athletics program. A women's heptathlon consists of 100m hurdles, shot put, high jump, 200m, long jump, javelin throw, and 800m. The current heptathlon world record belongs to Jackie Joyner-Kersee. Who, at the age of 26, achieved 7291 points at the 1988 Olympic Games in Seoul, South Korea (Silva & Caeiro 2021). Because the events have different measurement systems (meters, centimeters, seconds), the performances of each event are transformed into a common points system. This enables the scores to be summed up to a final score which leads to the overall ranking of the athletes. Due to the different measures, the International Association of Athletics Federations (IAAF) established three equations for the different types of events. These equations were derived by Dr. Karl Ulbrich and Jörbeck in 1954. In 1984, the technical committee, under lead of Emmanuel Rose, modified the system which has been used ever since.

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Combined events try to detect a multitalented athlete, someone who can sprint, jump, throw, and has endurance. Therefore, the winner of the decathlon/ heptathlon is crowned as king and queen of athletics (Hartmann 1977). The competition follows the principle of all roundness, which means that every single event should have roughly the same share on the total score (Westera 2007). The IAAF's scoring system should insure that performances in every discipline score approximately the same amount of points (IAAF 2001, Trkal 2006). The current scoring equations consist of three types: a linear, a progressive, and a regressive formula. The progressive curve illustrates an inverse probability of a high score when performances approach record levels. To put it simply, the more outstanding a performance, the less likely it is (IAAF 2001, Trkal 2006).

The constants which are applied in the formulas are shown in table one below. The role of the constants is to weigh the different formulas so the points from each event match the respective performance. The constants have been determined on basis of mean values of the 30 world's best specialists and the 100 worlds' best multiathletes in 1984 (Fröhlich et al. 2017). Since all world records are the limits of human feasibility, the scoring system recognizes them as roughly equivalent (Geese, 2004). Unfortunately, there could be no derivation of the constant's calculation found. There are three constants (A, B, C) for each event which are then inserted into one of the three equations.

**Table 1.** *Constants of the "IAAF Scoring Tables for Combined Events"*

| **Event** | **A** | **B** | **C** | **Unit** |
|---|---|---|---|---|
| 200-meter run | 4.99087 | 42.5 | 1.81 | sec |
| 800-meter run | 0.11193 | 254 | 1.88 | sec |
| 100-meter hurdles | 9.23076 | 26.7 | 1.835 | sec |
| High jump | 1.84523 | 75 | 1.348 | cm |
| Long jump | 0.188807 | 210 | 1.41 | cm |
| Shot put | 56.0211 | 1.5 | 1.05 | m |
| Javelin throw | 15.9803 | 3.8 | 1.04 | m |

*Source:* IAAF 2001, p. 24.

**1.** Track events include 100m hurdles, 200m, and 800m. They all follow a similar scoring curve to that of hurdles shown in Figure 1. P stands for points scored. A, B, and C represent the constants from Table 1 and T is time in seconds. The regressive curve follows the formula:

$$P = A * (B-T)^C$$

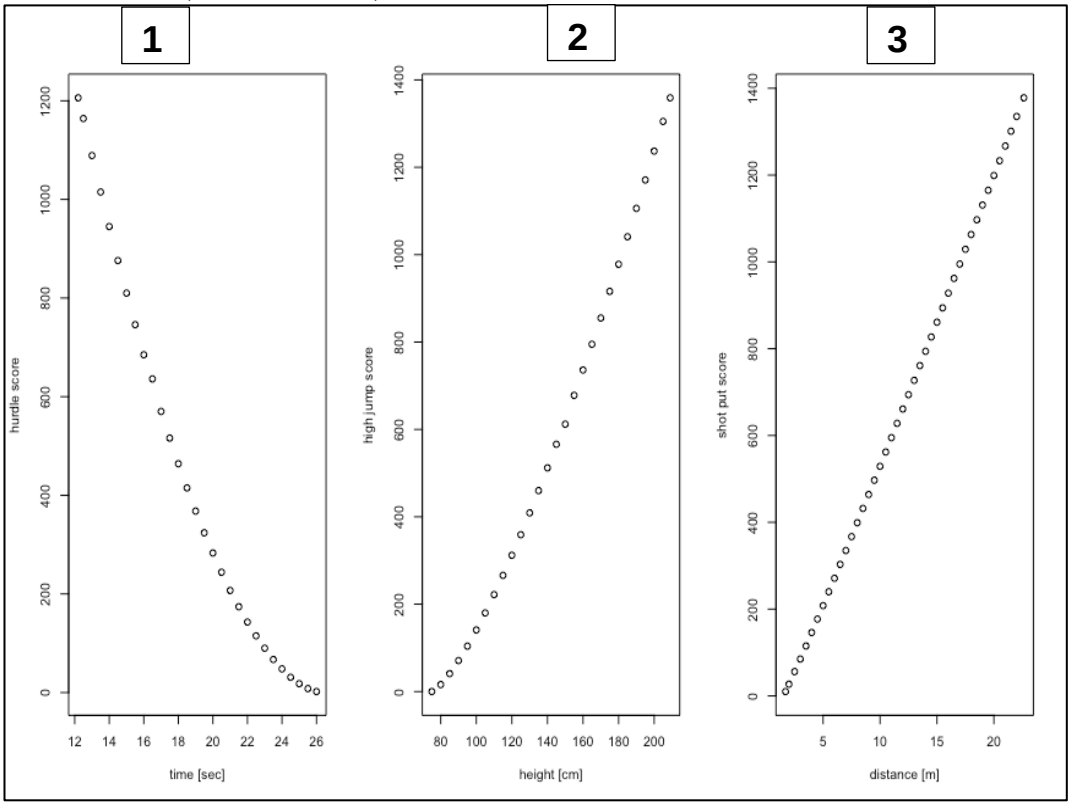
**2.** Jumping events include high and long jump. In Figure 1, jumping events are represented by the high jump score in column 2. M is the abbreviation for measurement of the jump in centimeters. The progressive curve follows the formula:

$$P = A * (M-B)^C$$

**3.** Throwing events include shot put and javelin throw. They are illustrated by the shot-put score in the right column with the number 3 in Figure 1. D stands for distance in meters. The linear curve follows the following formula:

$$P = A * (D-B)^C$$

**Figure 1.** *Illustration of the Current Three Heptathlon Equations: Track Events represented by Hurdles, Jumping Events represented by High Jump, and Throw Events represented by Shot Put. Highest score is represented by the Women's World Record (Status 04/2024)*




*Source:* Plotted with R-Studio by Theresa Vater.

*Literature Background*

As mentioned above, combined events refer to the principle of all-roundedness and try to detect the most versatile athletes (Barrow 2014, Westera 2007). But is the scoring system even valid for detecting a multitalented athlete?

A pioneer in performance analysis for combined events was Letzelter. In 1985 he already raised concerns about the unequal distribution of points in the scoring system (Letzelter 1985).

The ideal distribution of scores for a multi-athlete who achieves the same number of points from each event, should be approximately 14.3% for each of the seven events (100%:7). But is that the case?

Westera answered that question in his study from 2007, he found that hurdles have the greatest share on the final score with 16%, followed by 15.5% for long

jump, 15.4% for high jump, 14.8% for 200m, 14% for 800m, and in the end the two throwing events with 12.3% for shot put, and 11.8% for javelin. Fanshaw found that, on average, hurdles have the greatest proportion on the final score, followed by high jump, 200m, long jump, 800m, shot put, and javelin (Fanshawe 2012).

Besides the studies examining the descriptive statistics of combined events, like Westera and Fanshaw did, researchers tried to outline the uneven distribution of scores among events with a cluster analysis. Schomaker found out that decathletes can be clustered in three types: speed specialists, strength specialists, and endurance specialists (Michael Schomaker 2011). Several authors state that the sprint type is clearly favored over throwers and endurance athletes by the current decathlon scoring system because more points are available from track compared to field events (Barrow 2014, Fröhlich et al. 2017, Geese 2004, Park & Zatsiorsky 2011, Westera 2006).

There seems to be considerably less data for the heptathlon analysis in comparison to the decathlon scoring system. Like Decathlon, heptathlon can be clustered in three groups: 1) Speed type: 100m hurdles, high jump, 200m, long jump; 2) Strength type: shot put, javelin throw; 3) Endurance type: 800m (Fröhlich 2015, Heazlewood 2011). Researchers have found that the speed-based disciplines have a greater impact on the overall outcome compared to the throwing disciplines (Fröhlich 2015, Mekhrikadze et al. 2019, Westera 2007).

Considering, that hurdles seem to make up the greatest share with approximately 16% on the final score and is a speed-based event, the researchers of this paper wondered therefore if hurdles could serve as the greatest predictor for the total score.

In order to predict a heptathlon performance, regression models are used. Brodani discovered that 41% of variance can be explained by long jump. This means, long jump has the greatest influence on the expected value i.e., the athlete's final score (Brodáni et al. 2022). According to Fröhlich long jump has an explanatory power of 48% based on the $R^2$ value. Whereas in contrast, it is 7-8% for shot put, javelin, and 800m (Fröhlich 2015). According to further literature, the disciplines don't equally affect the final score.

*Study Objective*

Unfortunately, previous studies showed several limitations in their study samples. For example, small sample sizes and the inclusion of javelin results before 1999. The javelin's centroid was shifted forward in that year due to safety reasons (Backley 2000). That means javelin results before and after 1999 are hardly comparable and could therefore have caused an error in previous studies.

1. Therefore, the objective of this study is to re-examinate the score distribution for a large sample, only including javelin results from 1999 and onwards. The corresponding research question is: Is the data distribution calculated with the current heptathlon scoring system equally representing the seven single events?

2. Secondly, this paper aims to check which event is the best predictor for the final score. Therefore, the contribution of each event of the final score will be explored. The corresponding research question is: Is the event with the greatest share, also the best predictor for the final score?

## Methods

For this study, only heptathlon results achieved in 1999 or later were included. Even though the IAAF calculates with the same tables since 1984, in 1999 the javelin was redesigned to bring the center of mass forward (Backley 2000). This change was made to reduce the distances thrown because the athletes often reached distances close to the end of the field. If no change was made, this could endanger event workers and other athletes outside of the event area and unaware of any potential dangers. Due to this change javelin scores before 1999 are hardly comparable to those achieved in or after 1999. The sample includes heptathlon outcomes of World Championships from 1999 to 2023 and Olympic Games from 2000 to 2021.

Exclusion criteria are the following:

- Abrupted heptathlon
- No marks reached in one or more disciplines
- Athletes caught doping
- Ages outside 18-35

Data was gathered from publicly available sources like https://worldathletics.org/ (*World Athletics*), https://www.sportschau.de (*Sportschau*), and https://www.wikipedia.de (*Wikipedia*). The name, date of birth, nationality, ranking, measurement of each performance, scoring points for each event, and the overall score were entered into Microsoft Excel for processing. 433 heptathlon results from 19 events and 192 athletes were gathered.

To answer the first research question the descriptive statistics includes mean value, median, minimum, maximum, standard deviation, variance, and quartiles. It was conducted with the latest version of JASP 0.17.2.1.

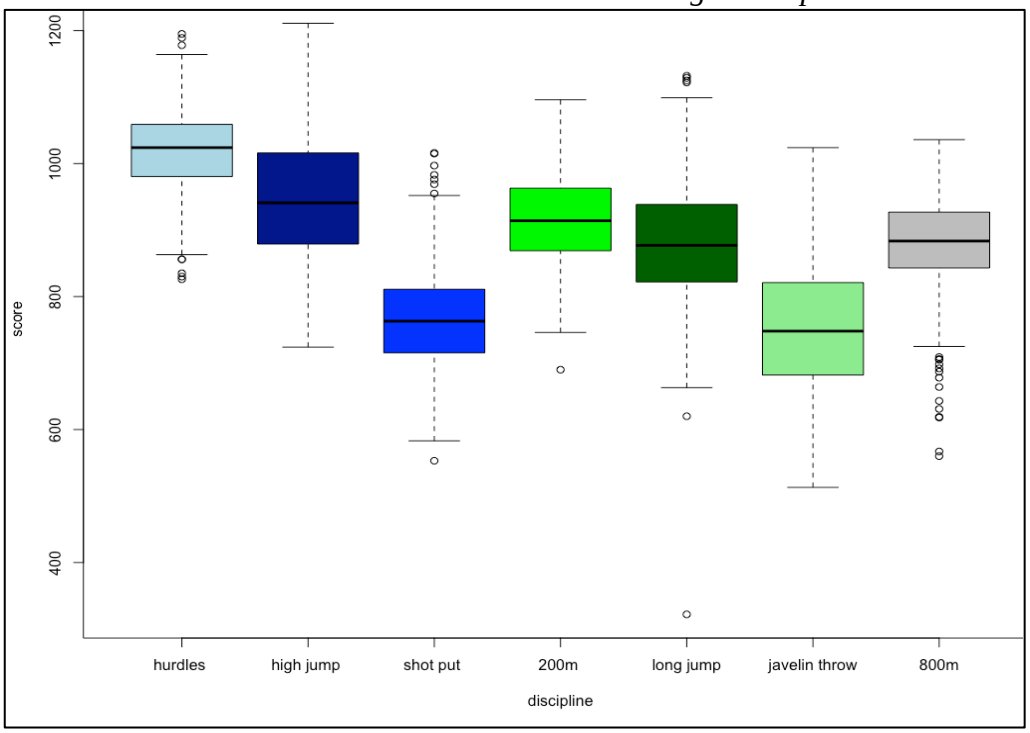
To test how each event, influences the final score, a multiple linear regression was conducted. The dependent variable is the final score, and the independent variables are the performances of seven events. A z-standardization was conducted to make the values of different measurements (m, cm, sec) of the performances comparable. At first, the measured performances had to be transformed into z-values. The z-standardization was calculated by this formula: $z= (\chi-\mu) / \sigma$. The mean ($\mu$) was subtracted from the original value ($\chi$) and then divided by the standard deviation ($\sigma$). R-Studio was used for plotting.

## Results

*First Objective: Distribution of Scores*

Figure two illustrates the distribution of the scores for the whole sample (n=433) based on the current IAAF scoring model. The seven disciplines are labeled in order of how they are competed on the x-axis. And on the y-axis are the corresponding scores achieved between 1999 and 2023 for World Championships and Olympic Games for each event. The mean age of the athletes was found at 25±3.5 years.

**Figure 2.** *Boxplots of Heptathlon Scores from World Championships and Olympic Games between 1999 to 2023 divided into the Seven Single Disciplines*




*Source:* raw data plotted with R-Studio by Theresa Vater.

The boxplot illustrates that on average the most points (1021±62) were gathered during the 100m hurdle sprint. Meaning on average, it has the greatest proportion of the total score with 16.8%, then high jump with 15.6% (948±88 points). The third greatest proportion is made up by the 200m sprint with 15.1% (916±69 points) followed by 14.5% (881±90) for long jump. The 800m run has on average a proportion of 14.5% corresponding to 880±73 points. The lowest share is accounted for shot put with a score of 761±78 points (12.5%) and javelin throw with 752±101 points (12.4%). The average total score is 6163±318. Most outliers were found for 800m, shot put, and hurdles. Another finding is that the standard deviation is higher for field disciplines (javelin±101, long jump±89, high jump±87, shotput±78) and smaller for track events (800m±73, 200m±69, hurdles±62).

*Second Objective: Multiple Linear Regressions*

To answer the individual influence of each event on the final score, a multiple linear regression was calculated in JASP. Due to different types of measurements (time or distance) in several disciplines, it is mandatory to transform the measured performance into z-values. The z-values make the various performances comparable.

The overall model predicted approximately 96% of the variance for the total score, $R^2$=0.957, $F_{(7,408)=}$1295.96, p<0.001. There were only significant associations between disciplines and the total score found (p<0.001).The hurdles (B=-65.06, SE=4.53, p<0.001, 95%CI= -73.96 to -56.14), 200m (B=-70.39, SE=4.67, p=<0.001, 95%CI= -79.57 to -61.21), and 800m (B=-70.81, SE=3.53, p<0.001, 95%CI= -77.76 to -63.87) show negative regression coefficients. Indicating the fewer the seconds, the greater the final score.

Vice versa, high jump, shot put, long jump, and javelin throw all show positive coefficients. Indicating the further or higher the jump/ throw, the greater the score. Long jump (B=118.33, SE=4.09, p<0.001, 95%CI= 110.28 to 126.37) has the greatest influence on the predicted score. It is followed by javelin (B=102.47, SE=3.60, p<0.001, 95%CI= 95.38 to 109.55) and shot put (B=85.85, SE=3.53, p<0.001, 95%CI= 78.92 to 92.78). For high jump it is B=49.37, SE=3.41, p<0.001, 95%CI= 42.67 to 56.01. Meaning a one-unit shift of the z-standardization for high jump indicates a mean change in the final score from 6162.5 + 49.37 to 6211.8.

**Table 2.** *Multiple Linear Regression*

| **Multiple linear regression** | | | | | | |
|---|---|---|---|---|---|---|
| **Event** | **Regression Coefficient B** | **SD** | **Standardizied regression coefficient ß** | **p-value** | **lower limit** | **upper limit** |
| Hurdles | -65.06 | 4.53 | -0.204 | <0.001 | -73.96 | -56.14 |
| High jump | 49.37 | 3.41 | 0.155 | <0.001 | 42.67 | 56.01 |
| Shot put | 85.85 | 3.53 | 0.270 | <0.001 | 78.92 | 92.78 |
| 200m | -70.39 | 4.67 | -0.221 | <0.001 | -79.57 | -61.21 |
| Long jump | 118.33 | 4.09 | 0.372 | <0.001 | 110.28 | 126.37 |
| Javelin throw | 102.47 | 3.60 | 0.322 | <0.001 | 95.38 | 109.55 |
| 800m | -70.81 | 3.53 | -0.223 | <0.001 | -77.76 | -63.87 |

## Discussion

*First Research Question: Is the Data Distribution Calculated with the Current Heptathlon Scoring System Equally Representing the Seven Single Events?*

According to the descriptive statistics, this study proved for a great sample (n=433) that the scores are unequally distributed. Shot put and javelin are particularly neglected in the athlete's final score. Descriptive statistics showed different proportions of the seven disciplines. The hierarchy found in this study is: hurdles (16.8%), high jump (15.6%), 200m (15.1%), long jump (14.5%), 800m (14.5%), shot put (12.5%), and javelin (12.4%).

The same share order is shown by Fanshawe (2012). Westera found a slightly different hierarchy for his sample of the all-time top 99 women's heptathlon which is: hurdles (16%), long jump (15.5%), high jump (15.4%), 200m (14.8%), 800m (14%), shot put (12.3%), and javelin (11.8%) (Westera 2007). Westera's Top 99 sample scores higher in long jump than this study's sample, leading to a different order where long jump has the second greatest proportion behind hurdles. So, it seems that the all-time top list is dominated by extraordinary long jumpers. Summing up, different samples lead to a different order of events in terms of shares on the final score.

Looking at the spread of the performances among all athletes, it is noticeable that the standard deviation is higher for field disciplines (javelin±101, long jump±90, high jump±88, shot put±78) and smaller for track events (800m±73, 200m±69, hurdles±62).

These findings go hand in hand with the one from Cox who examined decathlon samples. He concludes that decathletes who perform well in field events are favored in the final ranking (Cox & Dunn 2002). On the first look, this conclusion sounds contrary to the statement that sprinters (=track discipline) are favored over throwers (=field discipline). But is means that sprint disciplines share the greatest proportion of the final score and have a small standard deviation. This indicates that all athletes perform very well there. A strong foundation of sprint abilities is a prerequisite for multi-athletes.

Whereas with field disciplines, there is a smaller proportion of the final score, but wider standard deviations. Indicating that not everyone is performing very well there. These disciplines therefore serve to stand out from the crowd and achieve a better placement.

Perhaps one reason for a greater standard deviation in the field disciplines, especially javelin (±101) is because athletes are aware of the fact that there are not so many points to be scored here due to the scoring system. Smajlović states that improvement of 1cm in high jump equates to 0.111s in hurdles, 0.162s in 200m, 1.09s in 800m, 4.06cm in long jump, 15.74cm in shot put, or 54.19cm in javelin (Smajlović 2008). In competitions the high jump steps are increased by 3cm. If an athlete now fails only 1 further height, she needs to throw the javelin more than 1.5m further to compensate that! These small improvements in running and jumping events leading to large amounts of points, making it easier for athletes to get points from these disciplines as opposed to throwing disciplines. In order to

still create an incentive to train the throwing disciplines, the scoring system should be changed.

As a sidenote, it should be mentioned that the most outliers are found for the 800m run. According to literature, the accumulation of outliers here could be described as a "last-event factor" (Schomaker & Heumann 2011, p. 11). This discipline may not reflect endurance performance itself. It is distorted by the already existing score of the previous performances. For example, Bryan Clay (USA) led the first nine events in the Olympic Decathlon 2008, becoming last place in the 1500m run, being sure to win anyways (Schomaker & Heumann 2011).

Summarizing, the first section of the study proved that the data distribution calculated with the current heptathlon scoring system does not equally represent the seven single events.

*Second Research Question: Is the Event with the Greatest Share, also the Best Predictor for the Final Score?*

The multiple linear regression revealed long jump as the greatest predictor (B=118.33) for the final score. The remaining field disciplines have the following coefficients: javelin=102.47, shot put=85.85, high jump=49.37. The track disciplines show negative regression coefficients (hurdles=-65.06, 200m=-70.39, 800m=-70,81). Indicating the less time, it takes an athlete to reach an aim, the more points are scored.

Literature research showed different statistical procedures among studies. Fröhlich performed seven ordinary linear regressions and calculated that 48% of the variance of the total score can be explained by long jump. It is followed by a $R^2$ of 38% for 200m, 33% for hurdles, and 21% for high jump. Javelin, shot put, and 800m predict only 7-8% of the variance of the final score (Fröhlich 2015). If one runs several ordinary linear regressions, significant influences can be present in all coefficients. They might lose these as soon as you control for the influence of other variables, meaning, the more variables are controlled, the more realistic the model is. For this reason, a multiple linear regression is preferred over multiple single linear regressions. Brodani, who performed a step regression, points out the long jump (41.59%) as a key predictor for the overall score. But in contrast, he states that shot put (14.54%), javelin (11.29%), and 800m (13.11%) are most valid to predict the final score (Brodáni et al., 2022). There are many statistical ways to analyze performances which lead to different findings. However, researchers with different methods come to the same conclusion, that long jump is a key factor for the prediction of the final score in heptathlon.

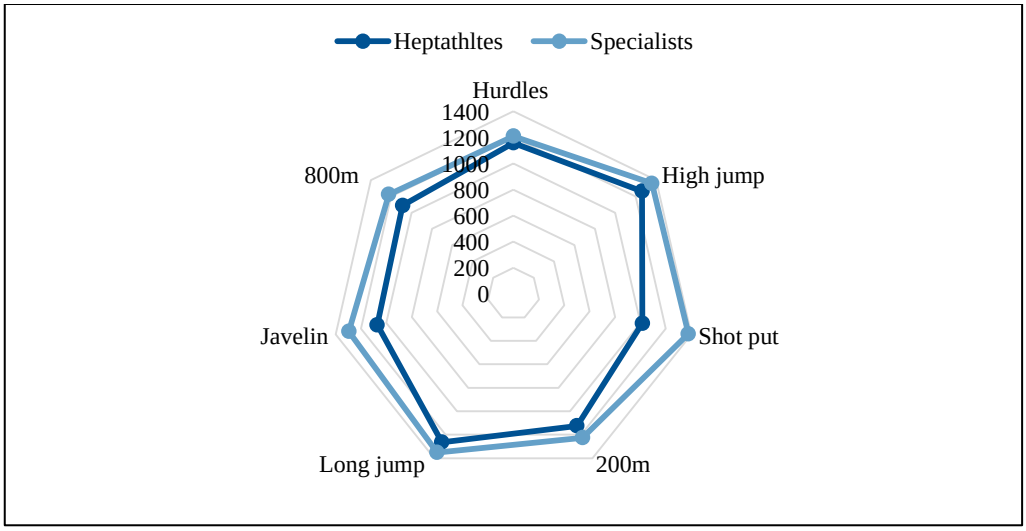
Summarizing, the second part of this paper, which was the exploration of the contribution of each event of the final score, revealed long jump as the greatest predictor. It is not the hurdle sprint, which is the event with the greatest share, that predicts the final score at best.

These findings can be outlined when looking at world-lead heptathlon performance of Jacky Joyner Kersee from 1988. Jacky stands out because she is additionally holding the heptathlon single event record of long jump with 7.27m

(IAAF 2024). This example once again underlines the importance of this discipline, but it still doesn't answer the question why the heptathletes score so few points in the throwing disciplines. Is it solely due to the scoring system?

Perhaps the reason why the throwing performance remains below average could be attributed to the limitation in heptathletes' ability to achieve greater distances due to their phenotype. Multi-athletes are far from looking like throwers (Broekhoff et al. 2003, Houtkooper 2001, Thorland et al. 1981). Clustering somatotypes of various track and field events showed that heptathletes and sprinters belong to the mesomorph type whereas throwers seem to be more endomorphic (Broekhoff et al. 2003). The different anthropometric properties seem to be reflected in the events. To emphasize this statement, Figure 3 illustrates heptathlon records in dark blue and world records of specialist shown in light blue. As you can see, the widest range is found for throwing disciplines. The disciplines where heptathletes differ anthropometrically the most from specialists. In addition to the large discrepancy in the shot put, it must be mentioned that the world record (22.63m) dates back to 1987. The recent title holders of the Olympic Games 2021 (20.58m) and world championships 2023 (20.43m) throw about 2m less. Reconsidering that the current scoring system uses the constants which were calculated on performances from the eighties makes the scoring system look obsolete. Which is another reason to update it.

**Figure 3.** *Radar Chart of the Women's World Records versus Heptathlon Records; Status 04/2024*




*Source:* Created by Theresa Vater.

There are several authors stating different approaches for the reevaluation of the system (Grammaticos 2007, Jiyingo & Xinmin 1995, Russomanno & Anselmo 2008, Westera 2006). Russomanno, introduces in his conference paper from 2008 a system which only considers two equations, instead of the current three formulas, for time-based and measurement-based events. Also he uses for the reference value a heptathlon record only and is not comparing heptathletes to

specialist (Russomanno & Anselmo 2008). A systematic review should be written comparing all the available models with each other.

Summing up, the descriptive statistics showed a highly uneven distribution of points. The greatest percentage of the final score is accounted to hurdles (16.79%), the lowest to javelin (12.4%). Indicating, that the scoring system itself is biased and less points are scored in throwing events compared to jump or sprint events. Looking at the rankings and Westera's study of the top 99 sample, it seems that the winners are overrepresented by athletes who perform well in jumping disciplines (Westera, 2007). Therefore, the current scoring system goes against the fundamental concept of organizing a competition for multi-talented athletes.

Looking solely at the performances, disregarding the scores of the single events, to check which event influences the final score most, long jump (B= 118.33) was detected as a key predictor, directly followed by javelin and shot put. It seems that the winners stand out especially in these events in order to score particularly high. But even tough an athlete performs over average in these events, the share on the final score is still smaller compared to an average hurdle score. For example, Anouk Vetter threw the javelin at the World championships 2023 in Budapest 59.57m which is close to the heptathlon record of 60.90m corresponding to 1046 points. Form descriptive statistics we know that score equals a median hurdle performance of 1026 points. That extraordinary example displays how hard it is to gather "good" points from throwing events and why most heptathletes don't want to put "too much effort" in throwing events even though they could play the decisive role on the podium. This example once more outlines the importance of updating the current system, so record-like performances get the points they deserve. A possible solution could be the elimintaion of the linear equation and including the throwing events into the progressive function (see Figure 1).

*Limitations and Strength of the Study*

This study is characterized by a particularly large (n=433) and broad (EC, WC, Olympic Games) sample size to describe the underlying problem. On one hand a large sample size is representative on the other hand it is easier to find significant effects. For the multiple linear regression, it would be interesting to see which values in cm, m, and sec correspond to an improvement of a z-unit. This would make to results easier to understand and should be implemented by further studies.

Due to the changed center of gravity of the javelin in 1999, it could have been that previous studies are biased in their results examining throwing events. The re-evaluation of the point distribution was therefore carried out in this study, in particular to eliminate this bias.

## Conclusion

This study proved that the current heptathlon scoring system shows an unequal distribution of scores among the seven disciplines. It especially neglects

throwing events (shot put and javelin) which on average make up 12% of the final score and favors sprinting disciplines (hurdles and 200m) with an average proportion of 16%. Even extraordinary performances in throwing events don't seem to gather noticeable more points than an average hurdle performance. The multiple linear regression revealed that long jump is the greatest predictor for the final score, followed by javelin.

The IAAF should reconsider their current scoring system. There are already several approaches by different researchers available. These authors recommend calculating the constants based on previous records of heptathletes/decathletes solely. Hopefully this could lead the seven disciplines into balance with one another. But because there are so many different mathematical approaches for the scoring systems of combined events, a systematic review is required to evaluate which model is most appropriate, so all disciplines of heptathlon carry the same weight.

Another approach to lead combined events to a balanced distribution of endurance, throwing, jumping, and sprinting events could be the rearrangement of the disciplines. For example, additional disciplines like discus and 1500m could enhance the weighting of endurance and throwing events. Of course, it would have to be checked whether this proposal would receive support from the athletes. But if the system does not change, athletes should consider which discipline is worth investing the most training time into.

This paper identifies the underlying issues with the current heptathlon scoring system, raising further questions that could guide the development of an alternative system. Therefore, this study serves as a catalyst for additional research in the field of heptathlon.

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