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Developing a formula for the comparison of athletics performances across gender, age and event boundaries based on South African standards

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Declaration

I, Sarel Wilhelmus Jacobus Bekker, ID number 4109185061087, hereby declare that the content of this dissertation is my own unaided work and that all quoted in this dissertation is properly acknowledged and referenced.

Signed: ____________________ At Vanderbijlpark on 28/01/2018

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Firstly and with humility, to GOD almighty for the ability and insight to conduct this work.

To my departed wife who had to listen to my ideas and her support during the whole process of investigation, reading and writing. I wish to thank her mainly for being there for me as a soundboard when needed.

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Abstract

The author addressed the need of parents, school teachers and athletic coaches to be able to assess the level of performance and to compare performances of individual athletes of either gender and in any age group. This was achieved by creating formulas for the following areas in track and field athletics:

- Correctly set base standards for all events from the results of 5 year weighted average performances.

- Use the base standards to determine comparative standards for all events in all age groups.

- Define a function to compare male and female performances in all events.

- For all events, generate tables with a range from 0 to 1000 as a comparative measurement.

These formulae were created using data from international and national meetings. Different case studies were used for each of the areas and the results were evaluated using the data. In all four areas, it was possible to define hybrid functions with a confidence factor better than 99%.

The final performance tables can be updated during revision periods (every 2 to 4 years) by using the national results for the last 5 years. These revisions will be required as implements, tracks and training methods change with time and this will then in turn influence the performances. This is evident from the continuous improvement of records in all events.

These tables will not only assist coaches to improve training techniques but it will also facilitate team managers to improve team selections, and it will open the options of meeting organizers to arrange meetings using different formats.

As this is a new and unique formulation for measuring performances at junior level in world athletics it can be used as a basis for future improvements in the field of comparative measurement for athletics.

Using these tables at senior level it may assist to settle arguments of performance comparisons that are not addressed by the current tables used by the International Amateur Athletics Federation (IAAF). It will also avoid the use of different tables for the same events in standard track and field athletics compared to those used for combined event competitions.

The author of the tables used by the IAAF has recognised this work as a new and unique development.

Future development will include the automatic update of all functions and creation of tables for publication from a standard Windows® based application. A companion application, using the results from this research, will be developed. This application will address all the administration functions required to conduct a meeting. It will include the preparation for the meeting, capturing of results during the meeting and result reporting after the meeting.

Keywords: Athletics, Performance, Comparison, Measurement, Tables, Age groups, Events, Competitions.

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Mathematical functions

In this dissertation the following mathematical functions (Stroud & Booth 2007) will be used in the models:

Linear: $y = m.x + c$

Logarithmic: $y = a.\log(x)$ and $y = a.\ln(x)$

Exponential: $y = a.b^x$

Polynomial: $y = \sum a_n.x^n$ with *n* a series of positive integer numbers.

In all functions *a*, *b* and *c* are constants.

Conventions

In all athletic publications the track events are abbreviated by adding the qualifiers directly after the distance without a space as required in conventional documentation. Examples are:

- 200m indicates a 200 meter race.
- 3000mSC indicates 3000 meter Steeple Chase.
- 5000mW indicates 5000 meter Walk.
- 110mH indicates 110 meter Hurdles race.

List of abbreviations

ASA	– Athletics South Africa
DT	– Discus Throw
HJ	– High Jump
HT	– Hammer Throw
IAAF	– International Amateur Athletics Federation
IOC	– International Olympic Committee
JT	– Javelin Throw
LJ	– Long Jump
mH	– meter Hurdles
mW	– meter Walk
PV	– Pole Vault
SASSA	– South African Schools Sports Association
SC	– Steeple Chase
SP	– Shot Put
TJ	– Triple Jump
USSASA	– United School Sport Association of South Africa

Chapter 1: Motivation for the research

1.1 Introduction

In the competitive environment of track and field athletics, it is easy to determine the winner of any event. When the problem arises about athletes participating in different events various arguments are used to declare the performance of one better than the other. These arguments are generally based on emotional reasons and quite often biased towards the preferred event of the person voicing an opinion in the argument. When people argue about the merits of performances, logical reasoning is quite often ignored. To venture into this field of research is comparable to what Gordon Rugg and Marian Petre called the "cockroach approach" (Rugg & Petre, 2007:13) due to the difficulty to convince people to accept new ideas.

At school level, the same arguments become even more difficult to answer. Athletes may not only participate in different events but also in different age groups. Gender differences also contribute to the complexity of the comparison of performances. A list of age groups and the available events for each age group, as approved by Athletics South Africa (ASA), can be viewed in the attachment "Technical Standards.docx".

This type of speculation requires an objective method, based on historical data, to give an answer to the question. The International Amateur Athletics Federation (IAAF), has attempted to solve this argument by creating a point scoring set of tables to compare performances of different events for senior men and women. These were originally only used for the combined event competitions during the Olympic Games and were later expanded to include all the events supported by the IAAF for seniors (President's message in the IAAF scoring tables publication). Although the concept is based on sound principles, it is still not settling the cross event arguments as it only sets standards within an event without appropriate inter-event considerations.

This will be discussed later. No attempt was made to extend these tables to the lower ages for school athletes.

1.2 Background of the study

To compare and evaluate performances is part of human nature. Measurement is the process or result of determining a physical quantity such as length, pressure, time and more. The study of how to measure and which tools to use in measuring is generally referred to as metrology. As stated by Stiglitz and Charlton (Stiglitz & Charlton, 2005:212): "A national/regional metrology system (is) a system that ensures that the measurements and tests required for all production, quality and certification activities are consistent and correct. This includes operational laboratories for primary and secondary physical standards."

In earlier measurements, the units of measurement were arbitrary selected and a group of people agreed on a unit and then adopted this as a standard. The classical example to illustrate this is to use the size of the width of a human hand to measure the height of a horse. This unit was later formalized, first for convenience and then from necessity (Baugh & Raymond, 2003:181). Today units are defined in terms of scientific quantities (Bekker, 2004:6).

In most cases it is essential to obtain exact measurements, but because all measurements are done using a tool, it implies that all measured results are approximations. To obtain more accurate results, continuous development is done in the construction and application methodology of measuring devices. In a large number of modern measuring devices computerized calculations are done. In the work done by Ernest Nagel in 1931 measurement is defined as "the correlation of numbers with entities that are not numbers". This definition is used in most measured values. Information theory recognizes that all measured values form a set of data which is inexact and statistical in nature. From this Douglas Hubbard (Hubbard, 2007:21) defines measurement as "A set of observations that reduce uncertainty where the result is expressed as a quantity".

A different type of measurement is done by using comparison. Most sport results fall into this category. Two athletes or teams compete and a result is obtained based on the rules for the particular sport discipline. A scoring system is used and the athlete or team with the highest score is declared the winner. Some sport disciplines, such as gymnastics and skating, still rely on human judgment. To obtain some sort of impartiality a panel of judges is used. The total score of a gymnast, in a particular event, is obtained by ignoring the lowest and highest scores an adding the remaining scores given by the individual judges in the panel. In his book on sport rules McFee (McFee, 2004:98) mentions that scoring in some sports is simply counting the number of successful conversions (goals, runs, tries) without considering the way in which it was achieved while in other types of sport all participants are successful but the score depends on the aesthetic considerations of how the effort was concluded. The score given will depend on the impartiality, knowledge and experience of the judge.

When applied to track athletics the performance of individual athletes in a particular event can be determined with a varying degree of accuracy. The variance will depend on the measuring devices used and human error in handling these devices. To eliminate, or at least equalize these errors, athletes participate in groups which implies that any errors due to instruments and/or the official will apply equally to all participating athletes.

A further complication arises at the finishing post where athletes may be so close together that the human judgment of who should be placed first and second can cause disputes. This method of using place judges is still in effect at most meetings. Only on higher level competitions electronic timing is used which can distinguish between athletes on time differences of 0,01 of a second. Even this precision has been disputed as the result depends on the accurate placing of the measuring equipment and the expertise of the person reading the photo result.

With the inception of combined event competitions (decathlon, heptathlon, etc.), and trophies that span across multiple events, such as a victor/victrix ludorum and total scores for teams participating, scorings systems become more complex. The question arises of how to determine a winner in such cases. The initial method, still in use at a large number of meetings, is to assign a score to the placing in each individual event and then add these scores to obtain the results of combined events. The different scoring methods will be explained and criticized in the next chapter.

The International Amateur Athletics Federation (IAAF) realized this predicament and in 1912 a working committee designed a linear scoring table based on the records that existed in 1908 for each of the events in the decathlon (10 events) to be used during the Olympic games of 1912. More on these tables and the work done in the USA as well as in Hungary and Portugal will be addressed later.

All the work done by the IAAF is based on world performances and senior athletes. Very little work is done at junior level (19 years) and only a single attempt was made in England for the age groups 17 years and 19 years. These tables were compiled by the English Schools' Athletic Association in 2011 and it is only used at the Track and Field Schools' Cup meeting.

In South Africa various competitions based on combined events are available and sanctioned by Athletics South Africa (ASA). This requires a table based system to ensure that the team with the best performances (not most 1st places) will be declared the winner. The first attempt at such a table was done in 1972, based on the linear table of the IAAF and using South African records in the age groups 14 to 19 years. Tables were developed for the specific events used during these approved meetings. No tables were developed for other age groups or primary schools.

1.3 Problem statement

To be able to resolve the arguments as stated in the introduction, the author will endeavour to determine if a formula can be defined to compare the performances of different events across the boundaries of age and gender.

This will be done by researching the factors involved in athletic performance, the relationships between events and using reliable available data from historic meetings.

The data will be obtained from public publications of competition results. At international level, this information is available on the website of the IAAF, and for South African results most are available on the author’s website, containing provincial and South African data since 1985.

As the currently available tables are not entirely acceptable and the fact that there are no comparative tables for school athletics, this research is unique and has not been done in any other country. The formulation will be done in such a way that the standards can be modified to those available in other countries. This will make the final product available and adaptable for junior athletics across the world.

1.4 Research objectives

To achieve the final formulation of a function for the comparison of events it will be required to establish sub-functions and thus to define sub-objectives. The sub-objectives are required to establish a foundation that will support the main objective.

1.4.1 Primary objective

The primary objective stems from the stated need to compare the performances of athletes participating in different events, different age groups, from any gender and in a large number of cases, at different venues. This implies a method of comparison that will accurately reflect a random performance in a particular event on a point scale that will be able to compare it to a different random performance in another event. If the two performances are reflecting the same state of ability from the athletes, the same level of training and the same effort to achieve the performances, the tables should reward the same point to both performances.

To define a function that will correctly award such a variety of performances, the nature of performance variations within any event must be determined. It will also be a requirement to determine acceptable base standards for each event where these base standards will be accepted as equivalent for comparison purposes.

1.4.2 First sub-objective

To ensure validity of individual tables, all tables should be seeded from a reliable standard performance that is based on sound principles. These values must be derived from statistical data for each event. In this study, it will be determined if a relation between events can be established in such a way that a single standard can be used to accurately determine comparative standards for other events.

1.4.3 Second sub-objective

The effect of age difference within a specific event will be researched to determine if a function is available to generate reliable standards using standards already determined in a specific age group. This objective is essential as there are no national competitions for all age groups in all events and standards will have to be obtained from reliable data in other age groups. At national level athletes only participate in the age groups 10 to 13, 15, 17 and 19 years. At lower levels of competition athletes participate from age 6 to 19 years at school level and 21, 23 and senior for post school athletes. Reliable data is thus only available for events at national level and the other standards must be derived from these.

1.4.4 Third sub-objective

Finally, the relationship between boys and girls participating in similar events will be investigated to determine if the ratio in performances is consistent across the range of all events. It must be determined if this difference is a simplistic ratio or a complex function.

1.5 Research Method

In essence research is a human endeavour to add to the pool of knowledge in different spheres of life. This will be achieved through creation, formulation, testing and confirmation of a hypothesis (United States Government, 1938: 62). Depending on the aim of the research different approaches or methods can be used.

All research is based on the collection of data of a type and format applicable to the type of research to be conducted. This data is then analysed and conclusions are reached which will prove or disprove the original viewpoint of the researcher.

Methods of research can be scientific, analytical, historical, constructive or empirical. This last mentioned method uses a formulation as a research statement and then uses the analysis of the data to determine the feasibility of the formulation.

A specific subset of the empirical research method is the formulation of case studies. The case study as a research method has been used successfully by a large number of researchers. Yin defines the case study research method as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used (Yin, 1984: 23). This approach is applicable to the specific research that will be conducted. This is a qualitative method that will be applied to a set of real data to formulate a prediction in related areas.

1.6 Research ethics

All data that will be used in this research is available from open publications and the results of any athletics meeting are in the public domain. No permission is required to use this data.

The only ethical consideration that will be required is to get approval from the South African controlling body, Athletics South Africa (ASA) and acceptance by the South African School Sports Association (SASSA) before the generated tables are published for general use during meetings.

Without this consent and acceptance the tables can still be published as a set of private tables but it will not carry the required weight as a standard table to be used by all schools at all meetings. This will forfeit the reason for the research to provide a tool that will objectively settle the arguments about performance comparisons.

1.7 Research layout

The research dissertation will contain the following chapters:

Chapter 1

Introduction to the problem.
Background information required to understand the problem.
Defining the research statements and research objectives.

Chapter 2

Literature review of the history of athletics.

Related requirements for measurements.

Chapter 3

Delimitations.

A critical review of current tables.

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Chapter 4

Identification of available data.

Case formulations.

Chapter 5

Results analysis.

Criticism and deviation analysis.

Final formulations.

Update procedures.

Chapter 6

Relevance of the results.

Contribution to sport science.

Chapter 7

Conclusions.

Future research possibilities.

Chapter 2: Current systems' literature review

2.1 Introduction

The need to measure and compare started as a means of trade and value was added to objects for trading. Even today some nations still do not use money but rather trading. In the early history of Europe, trading in furs and animal skins was a common practice (Jones, 1975:151). Labola, meaning "the price of a wife", is a tradition that is based on the belief that the couple marrying should become close to each other's families. During labola the two families will discuss how much will be paid, normally using cattle as an indication of wealth, for the groom to marry the bride. As with most ancient traditions labola is often subject to distortion in the modern world. In an article published in News24 (01 August 2013), Nkosinathi Mokoena asked the question "Is Lobola still relevant?" He then commented on this tradition as hiding behind "culture" as a means of enrichment.

The measurement of athletic competitions started as merely a show of strength or speed by competing against each other. (Tyrrel, 2004:85, 155, 218, 241) With the changes in communication, the comparison had to be changed to include the comparison of results of strength or speed at different venues and between different disciplines. This led to the development of measuring methods and devices.

2.2 Measurement as a science

2.2.1 Metrology

The word metrology can be explained as the art or science of measurement. When measurement is considered it is required to first investigate the need for the measurement. This need existed from the earliest ages when man wanted to compare or convey information about the parameters of different objects. (Bekker, 2004:8) A parameter can be described as some value such as the length, height, weight, colour, etc. of the object.

Initially the human body parameters were used to measure other objects (Savage & Ehrlich, 1992:1-5). Some of these measurements are still in existence but they have been refined and defined with more precise values (Feather, 1959:11,150). Examples of these older types of measurements are:

- The width of the 'average' man's thumb was called an inch.
- The length of the 'average' man's foot was called 1 foot.
- The length of the 'average' man's stride was called 1 yard.

As these types of measurements caused a lot of arguments they were 'standardized' by using the measurements from a specific person, normally from the royalty. Imprints were taken and used as a measuring tool. Not so long ago it was still common practice in some countries to measure and claim a farm by using the measurement of a 'Days ride on horseback'. The person could claim the land encircled between sunrise and sunset. (If he did not return to the starting point by sunset he lost the total claim and got nothing!) The farmers in the Cape wine area could claim a farm by walking a horse for 1 hour in four directions to form an enclosed area (Keppel-Jones, 1961:27).

During the industrial revolution technology improved and the need for more accurate measurements became essential and the different quantities to be measured increased. The standardization of measurements culminated in the current SI units (Fay & Golomb, 2002:303).

2.2.2 Measuring instruments

To be able to measure it is necessary to use the appropriate instruments. The accuracy of the measurement will then depend on (a) the accuracy of the instrument that is used and (b) the skill of the person using this instrument. It is therefore not only required to develop good tools but also to train people in the correct use of these tools (Krebs, 199:136). An additional complication is introduced when the results of the measurements are interpreted.

Consider measuring a long distance, say about 1 kilometer, with a steel tape measure with a length of 100 meters. The actual length of the tape is questionable, as it will depend on the temperature at the time it is used. As the tape must be moved a few times, the exact location of each starting point is also questionable. Lastly if the person using the tape allows slack during the measuring process the method used to handle the tape is also questionable. When the final reading is then recorded as a value of 1,0235 kilometeters the next person using these results, not knowing how it was obtained will be misled and it could be interpreted as a very accurate reading (Churchman & Ratoosh, 1959:92). It is thus clear that the correct measuring tool must be selected, the correct method of handling the instrument must be observed and a knowledge of exactly what the defined accuracy will be is needed. Without these properties any measurement result would be meaningless and the use of such results can lead to misconceptions of the true values measured (Churchman & Ratoosh, 1959:169).

2.2.3 Accuracy and Precision

To say that a measured value is accurate can be extremely misleading. The accuracy of a reading must be clearly defined to ensure that all persons using the result will understand the significance of the value. For example, if the height of a tall tree was to be measured, for most people a deviation of 10 meters would be acceptable, but if the information were to be used by a scientist monitoring the growth of the tree this would be unacceptable. Accuracy is closely linked to the error in measurement or deviation from the true value of the measured object (Kyburg, 1984:125).

There are two standard ways of expressing the accuracy of a value:

The accuracy can be expressed as the number of significant digits (Nagel, 1931:341). This method is normally used where very large numbers are involved. For example, if the accuracy of a distance measurement is expressed as 3 significant digits and a value of 342 000 meters is specified then the first 0 is significant and only the last two zeros can be any other value. On the other hand if a value of 547 647 is given, the last two digits are non-significant and may be misleading. The value should be given as 547 600.

The second way of expressing accuracy is by specifying the maximum deviation from the measured value as a percentage. In this case there should be an additional qualifier to indicate if the deviation will be the same for higher and lower values or if two different percentages should be used. An additional problem with a percentage specification is that it is often not clear whether the percentage should be applied to the actual measured value or to the expected value. If accuracy is specified as a percentage with no sign, it is normally considered to apply in both directions. The correct way of specifying accuracy as a percentage can be one of the following: (a) ±2% ev or (b) +2%; -1,7% ev (ev = expected value) (Bekker, 2004:2)

A poor way of expressing the accuracy is 5% max. This can be interpreted as ±5% of the measured value but it could be as bad as ±5% of the maximum range of the instrument, which can be a considerable deviation at the lower end of the measurement. Some manufacturers use this way to hide deficiencies and to publish a 'very good' specification such as 0,5% maximum. If this specification is applied to an instrument with full-scale value of 100 units and the actual reading is 100 units the error will only be 0,5% or ±0,5 units. This appears to be good but because the same error will be found for all other measure values and if a value of 10 units is measured then the true value could be between 9,5 units and 10,5 units. The actual accuracy at this point will be 0,5/10 x 100% = 5% which is 10 times more than the published accuracy (Bekker, 2004:2).

Precision and Accuracy are quite often used in the same sense. They are not the same! Precision can be defined as the repeatability of a measured value. If an actual value of say 20 units is measured using a specific instrument and it gives a reading of 17 units, the accuracy is most certainly not acceptable as it produces an error of 15%! If the same measurement is repeated and this instrument continuously produces a reading of 17 units (or close to 17 units), it is however a very precise instrument, as it will repeatedly give the same reading. Precision can be calculated as the maximum deviation as a percentage of the average obtained reading (Bekker, 2004:3). In general it can be said that accuracy depends on the construction of the instrument and precision is determined by the calibration of the instrument. A high precision instrument, correctly calibrated, will also be an accurate instrument.

2.2.4 Sensitivity, Threshold and Resolution

Sensitivity is an indication of the smallest visible change that an instrument can detect (Tweney & Hughes, 1958:215). The sensitivity of an instrument is expressed as the ratio of the response of the instrument to the parameter being measured. The reference for the ratio is normally the full scale value of the instrument.

Threshold is the actual value of the smallest detectable change in the measured value. This might not be readable on the scale but it will be visible as small changes in the result. Threshold is closely linked to sensitivity but the threshold is the actual smallest value of the measured value whereas the sensitivity is a ratio (Tweney & Hughes, 1958:1020).

The resolution of an instrument is the smallest possible change in value that can be measured by the instrument. This is linked to the scale of the instrument and the type of instrument. This value can be a few times larger than the threshold value. In well-designed instruments the resolution is equal to the threshold (Bekker, 2004:4).

As an example, consider two stopwatches. The first displays Hours and Minutes and the second watch will display Hours, Minutes, Seconds and tenths of a second. They are started at the same time and both stopped after exactly 4 hours. The first watch displays 4 hours and 1 minute while the second watch displays 4 hours, 2 minutes and 4,6 seconds. Both watches can record a maximum of 12 hours.

Precision:

Stopwatch 1 can only display to the nearest minute while stopwatch 2 can display 1/10 of a second. Stopwatch 2 is thus the more precise stopwatch.

Accuracy:

Stopwatch 1 has an error of 1 minute in 4 hours. This is a 0,417% deviation from the true value while stopwatch 2 has an error of 2 minutes and 4,6 seconds which is a deviation of 0,975% from the actual value. Stopwatch 1 is thus more accurate.

Threshold and Resolution:

In this example both these values will be the same if the definition of the units is applied. Stopwatch 1 has a value of 1 minute while stopwatch 2 is better at a value of 0,1 second.

2.3 Measurement units

2.3.1 The need for standards and units

Before any measurement can be done it is required to set standards that can be used as a consistent comparison of values (Hubbard, 2007:21). The original standards previously mentioned are not clearly defined and will therefore lead to variations in the interpretation of measured results.

With the advancement of technology it is possible to set standards obtained from physical properties. These standards are known as primary or fundamental standards (Fay & Golomb, 2002:303). Other standards can be derived by combining the primary standards. These are then known as secondary or derived standards.

The requirement of any standard is reproducibility. Using the definition of the unit it must be possible to reproduce the same unit in a laboratory anywhere in the world to be used as a reference. The names used for each standard must also be standardized to enable scientists to communicate the meaning of such standards (Fay & Golomb, 2002:303).

The original standards derived were those for time, length and mass. Of these the only true standard was that of time as different countries adopted their own standards for mass and length but all of them used the second as a time standard (Fraser, 1987:72).

Any measurement consists of two parts namely the numerical value and the unit name. The value 87 (numerical value) has no meaning until the unit it represents is specified. If the unit is added, such as 87 s (87 seconds) or 87 kg (87 kilogram) then meaning is added to the numerical value. The numerical value conveys the quantity and accuracy of the measurement and the units the interpretation of the measurement. It is thus important to always add the units to a measured value (Cavendish 2003:694).

2.3.2 Standard systems

In 1790 the French Academy of Science proposed a new single set of universal standards. They proposed new standards for length and mass. The time standard of 1 second equal to 1/86400 of the mean solar day was kept unchanged. They proposed that the meter should be defined as 1 ten millionth of the distance from the North Pole to the equator, along the meridian passing through Paris. The proposed unit for mass was the gram defined as the mass of 1 cubic centimetre of distilled water at 4 °C and at normal atmospheric pressure of 760 mm mercury (Hubbard, 2007:21).

As the length standard could not be reproduced in a laboratory, other countries were reluctant to adopt these standards (de Morgan, 1854). Nearly 20 years later, in 1875, 17 other countries joined the French. The British scientists modified the system slightly by using the centimetre instead of the meter, calling it the CGS (centimetre-gram-second) system. In 1935 many countries adopted a new standard developed by Giorgio, an Italian engineer, who added the Ampere (unit of current) as a fourth fundamental unit. This system was called the MKSA (meter-kilogram-second-ampere) system. Shortly after this the important SI system evolved from the MKSA system and in 1945 it was adopted as the universal standard (International Bureau of Weights and Measures, 2006:121).

At the same time, two secondary standards were also included namely the radian for plane angles and the staradian for solid angles. An important characteristic of the SI units is that they can be reproduced in a laboratory. These definitions still apply today (International Bureau of Weights and Measures, 2006:124).

2.3.3 Dimensions

The dimension of a unit depends on the units used to describe it in the specific system. The only universal dimension is that of time. It can be expressed in seconds, hours or years, but the dimension is always time. To distinguish between dimensions and units, dimensions are written in square brackets. As an example, consider the units and dimensions of acceleration. The dimensions of acceleration is expressed as:

$$[acceleration] = \frac{[speed]}{[time]} = \frac{[distance]}{[time]^2}$$

The units of acceleration consist of the components derived from the dimensions as:

$[acceleration] = \frac{[distance]}{[time]^2} = \frac{meter}{second^2} = m/s^2$ (Bekker, 2004:10).

2.4 History of the Olympic Games

2.4.1 Ancient games and the origin of the Olympic Games

The origin of the Olympic Games was from an athletic festival that originated in ancient Greece. These games (according to legend), were founded by Heracles (the Roman Hercules), a son of Zeus. Different types of games were held throughout Greece but the Olympic Games were the most valued of all. The ancient Olympic Games were scheduled from the 6th of August to the 19th of September on a four year cycle. These games were regarded as a culmination of all sport events to the extent that references are available indicating that the 4 year period between games was used as a time standard known as an Olympiad. These games, like most Greek games, formed an intrinsic part of their religious festivals. These festivals were held in honour of Zeus at Olympia in the city-state of Elis in the north-western Peloponnese. It is however interesting that the first Olympic Games recorded in writing were held in 776 BC. During this meeting, Coroebus (running naked) won the only track event of the meeting. This event was known as the "stade" which was a distance of approximately 192 meters. This made Coroebus the very first track Olympic champion in history ([Online] IAAF.org: History of the Olympic Games).

In the year 393 AC, the Roman emperor Theodosius I, a Christian, abolished the Games because of their pagan influences (De Coubertin, 1997).

2.4.2 Modern Olympic Games – The revival

In the late 19th century Pierre de Coubertin (a French aristocrat) started a movement to revive the Olympic Games. Although he was motivated to do so by A. Brooke, he never mentioned Brooke in any of his contributions. Coubertin's attempt to get France interested in athletics as a sport did not generate any enthusiasm but he persisted with his efforts and he founded a sports organization in 1890. It took 2 more years before Coubertin managed to gain support for his idea to revive the Olympic Games. He was given the opportunity to address a meeting of the Union des Sports Athlétiques in Paris. The delegates at the conference were convinced and a unanimous vote for the revival of the Olympic Games was tabled. Coubertin was tasked to head and constitute an international committee to organize the Games. This committee became the International Olympic Committee (IOC; Comité Internationale Olympique) and Demetrious Vikelas from Greece was selected to be its first president. Because of the Greek origin of the games, Athens was chosen as the location for the first meeting of the modern Olympic Games (Bronwell, 2008:156).

This first modern Olympic Games was held in the first week of April 1896. The Greek government was unable to fund the construction of a new stadium but a wealthy Greek architect, Georgios Averoff, donated one million drachmas (more than R1 000 000) to restore the old Panathenaic Stadium (built in 330 BC), with white marble for the new Olympic Games. The first new Olympic Games were not widely publicized and thus contestants were not representing their nationalities but they participated as individuals at their own expense. Some of the contestants were tourists with athletic abilities and when they became aware of the meeting, they were allowed to enter for participation during the Games. Athletes wore their individual club colors and not that of the nationality they represented (IAAF website – Revival of the Olympic Games) (Bronwell, 2008:28).

During this first Games athletes participated in pole vaulting, sprints, shot put, weight lifting, swimming, cycling, target shooting, tennis, marathon and gymnastics. All swimming events were held in the Bay of Zea, which is in the Aegean Sea. The winner of a gold medal, Alfred Hoyos Guttmann later described it by saying: "I won ahead of the others with a big lead, but my greatest struggle was against the towering twelve-foot waves and the terribly cold water." The total number of athletes entered for this meeting was approximately 300 and they were representing thirteen different countries ([Online] IAAF.org: Revival of the Olympic Games).

For a complete overview of the history of these games, refer to the annexure “Olympic Games History.docx”.

2.4.3 Rules and Regulations

In the modern games the IAAF allocate the venue of the games to a city and not to a country (Handbook: IAAF Rules,2012-2013). The choice of the city is the prerogative of the IOC. Application to hold the Games is made by representatives of a city with the support of the national government (IAAF Handbook, 2012-2013).

Up to 1970 only amateur athletes were eligible for participation at the Olympic Games. Since the 1980s, and at the request of some sport professionals, events were opened to professional athletes. This was originally strongly opposed by amateur sport bodies but currently the Games are open to all. These open events now include some of the top professional athletes in basketball and soccer (Goldstein, 1989:135).

To be able to cater for the vast variety of sport cultures the Olympic Games were divided into two main disciplines. The Summer Olympic section includes aquatics, archery, athletics (track and field), badminton, baseball, basketball, boxing, canoeing and kayaking, cycling, equestrian sports, fencing, field hockey, gymnastics, team handball, judo, modern pentathlon, rowing, sailing (formerly yachting), shooting, softball, soccer, table tennis, tae kwon do, tennis, triathlon, volleyball, weightlifting and wrestling. In 2009 the IOC voted to add women's boxing to the 2012 program, as well as golf and rugby sevens to the 2016 program. The companion Winter Olympic Games includes all the skiing and related events ([Online] IAAF.org: Announcements).

2.5 Measurement in track and field events

2.5.1 The need for measurement

Measurement is an essential element of all sports in two ways. First, measurements are taken to determine the outcome of an event, such as which runner was fastest or which javelin-thrower had the best distance. Second, measurements are used to communicate the agreed rules and regulations of a particular sport. It would be unfair, for example, to claim a world record in the 20 km walk event if the measured distance is not accurate.

The starting point for any measurement is the unit of measurement. For it to be useful, everyone must agree on which unit to use and what it means. In contrast to the precision of today, units of measurement in the past were often based on human features. Some examples are the cubit which represented the distance from a person's fingertip to his elbow and the definition of an acre was the area of land that a team of two oxen could plough in one day. These units were not comparable as people vary in size and the work-rate of oxen depends on a number of external factors (Bauch & Raymond, 2003:196).

To improve accuracy of measurement, people soon realized that units must be based on agreed standards. These days, most units of measurement used are those of the International System of Units. In this system, seven of the units have been selected to be base units. Larger or smaller multiples are obtained by combining the unit with an appropriate prefix. The base units most often encountered in sport are the meter, the second and the kilogram (International Bureau of Weights and Measures, 2006:124).

With the pressures of international competition comes a demand for increasingly accurate and fail-safe measuring devices. Science and technology play an important role in developing more sophisticated measuring devices for use in major sporting events. Science can explain the way we use the forces of nature in various sports. Friction, air resistance and gravity are all forces that are important in sport. Understanding and measuring these forces can help athletes improve their technique and also lead to improvements in the design of the equipment. In addition, manufacturers of sporting equipment, clothing and playing surfaces constantly rely on measurements to improve their products in the quest for the next world record or just to provide safe and reliable facilities and equipment (Williams & Hodges, 2004:410).

Everywhere in sport, people are measuring: the distance of a hammer-throw, the time of a race, the number of tries scored, the dimensions of a field and many more. Sometimes the difference between winning and losing is just 0,001 of a second which is a difference that can only be determined by electronic timing devices. It was remarked during the Sydney Olympic

Games by Mr Berthaud of Omega (the suppliers of the timing equipment): “maybe we are too fanatical about measurements but, then again, there are few things more frustrating than an inconclusive result”. When Sydney hosted the Olympic Games in 2000, it provided world-class facilities for 27 different sports. Measurement was essential to ensure that these pools, courts, tracks and fields complied with Olympic regulations ([Online] IAAF.org: Feedback on the Sydney Olympic Games).

2.5.2 Measurement of Time

Hand-held stopwatches have become more accurate, but they depend on human judgment and reaction times. This influences the accuracy of measurements and reported times will be uncertain by at least 0,2 of a second. This implies an error of approximately 2 meters in a 100 meter race (Sanders, 1998:21).

Such inaccuracy presents considerable difficulties. For example, in the 1960 Olympic Games in Rome, Australia's John Devitt and America's Lance Larson touched the wall at the same time in the final of the 100 meters freestyle swimming event. Two of the three 1st place judges had Devitt as the winner, but two of the three 2nd place judges had Devitt second. In contrast the timekeepers had no doubt about the result. All three on Devitt's lane gave him 55,2 seconds, while the timekeepers on Larson's lane gave him 55,0, 55,1 and 55,1 seconds, all faster times than that of Devitt. But, as all 6 time measurements were within 0,2 of a second (the expected error in measurement) the times did not help to decide the winner. Using the rules of placement, the decisions by the 1st place judges were upheld and the race was awarded to Devitt. Both swimmers were given an official time of 55,2 seconds (Perry, 2011).

In 1964 an electronic quartz timing system was introduced and used for the first time in international events. This improved the measurement of time to an accuracy of 0,01 of a second. The computerized timing systems used in events today have increased the accuracy to less than 0,001 of a second, which is 10 times the accuracy required under the rules (Trkal, 2003:15).

Judging very close finishes in track events remained a problem until the introduction of photo-finish video cameras at the finish line. These were originally film-based cameras which implied that for any dispute athletes and spectators had to wait until the film was developed before the results were made official. The introduction of the vertical line-scanning video system in 1991 totally removed human judgment and reactions from the timing and judging of world class running events. The starter's pistol is linked to a transducer, which detects the sound made when the starter pulls the trigger. The transducer is connected to a timing computer, which starts to count immediately when it receives the signal. Connected into this system is a high quality video camera located at the finish line. This produces the official time and a video image of the athletes as each one passes the finish line. The video camera scans a thin line aligned with the finish line up to 3000 times per second. The video image of each athlete as they actually cross the line is shown superimposed with a grid that shows the time for each competitor. The person operating the video system will adjust the marker line to each athlete in the race and then record the displayed time. This system allows judges to declare the result more quickly and more accurately. Additionally two parallel infra-red beams can also be located at the finish line which are directly linked to display boards within the stadium. They will then provide spectators with an instant but unofficial time for the race (User manual MacFinnish, 2004:10).

Reaction time is the time that elapses between the moment a stimulus is detected by the brain and the moment a response starts. In laboratory tests it was found that nobody can react to a stimulus in less than 0,110 of a second. Sprinters are coached to have excellent reactions to ensure that they leave the blocks as quickly as possible after hearing the gun. Australia's Cathy

Freeman was tested and her best reaction time was recorded as 0,223 seconds during the 1995 World Championships women's 400 meters final (Barrow, 2012).

Today all starting blocks contain a transponder linked to the starter's pistol and any reaction time less than 0,11 of a second is used to trigger an automatic recall and identification of the athlete responsible for the false start (Perry, 2011).

In 1996 (Atlanta) two sprinters claimed victory in the women's 100 meters race. It was only possible to separate them by using the photo finish cameras. The athletes involved were American Gail Devers and Jamaican Merlene Ottey. The electronic timing official recorded 10,94 seconds for both athletes and when Devers was awarded the gold medal, Ottey protested. This protest was rejected as images from the finishing line indicated that Devers crossed a bare one five-thousandth of a second ahead of her. This episode shows how accuracy is crucial to the smooth running of the Olympic Games. The Swiss watchmaker Omega, which holds the coveted role of official timekeeper, is constantly updating its technology to ensure the most accurate results possible. In Atlanta (1996), cameras were taking 1 000 images per second. At the Summer Olympics in Beijing, Omega updated to digital cameras that were 3 times faster, taking 3 000 images per second. These accuracies are required to not only ensure the correct presentations of medals but can also influence the name of the person responsible for setting a new world record ([Online] IAAF.org: Feedback on the Atlanta Olympic Games).

Even today, there are times when athletes still contest their results. During the Sydney Olympic Games an athlete, Christophe, said '"I had the feeling I was first but I came in third". Mr Berthaud, Omega's Olympic Manager, commented by saying "Yes, of course it happens, but they can come and see the images that we have taken, frame by frame and we'll show them exactly at which point the finishing line was reached" ([Online] IAAF.org: Feedback on the Sydney Olympic Games).

In Beijing, Omega used 450 technicians and engineers as well as more than 1 000 volunteers, to ensure that timing equipment at all events was working. It is in contrast to the first Olympic Games in 1896 when judges supplied their own stopwatches made by diverse watchmakers. Several judges were assigned to each athlete and given that "not all judges have the same reaction time, or the same eye accuracy," an average of the timing was taken. The handbook of the IAAF Rules prescribe that hand timing must use three judges to measure the 1st place. If two record the same time, it is used and if all three are different, then middle time is used as official (IAAF Handbook: 2012-2013, Rule 165.8 85).

Omega was first appointed as official Olympic timekeeper at the 1932 Games in Los Angeles and has introduced several innovations in the subsequent decades that are now synonymous with sports timing. The first digital camera simplified things when it was introduced to the games in 1988. No longer would assistants have to run rolls of film to be developed in the dark room. But even as most human error has been removed from competitions such as races, marathons and swimming, the timekeeper is still introducing new innovations ([Online] IAAF.org: Publication on rulings).

Such an innovation was the incorporation of GPRS technology to provide more time recordings at regular intervals during the marathon. According to the regulations the timekeeper must provide time recordings for the marathon at five kilometre intervals. The same applies to half marathon races. But, using the GPRS technology, it transmitted additional data via GSM for 26 more points during the marathon in Beijing ([Online] Swisstiming.com).

2.5.3 Measurement of distance

For the measurement of distances similar problems are encountered. During the first meetings it was just necessary to determine the winner of a particular race. The distance was not of primary importance and quite often the venue dictated the start and finish positions rather than the distance of the event (Perros, 2001).

In 490 BC, the Greek soldier Pheidippides ran from Marathon to Athens (about 25 miles) to inform the Athenians about the outcome of the battle with the invading Persians. After delivering his message of the Greeks' success in the battle, Pheidippides fell to the ground and died. In 1896, as part of the modern games, it was decided to have a race of approximately the same distance in commemoration of Pheidippides (Perros, 2001).

During the first several modern Olympics, the marathon, named after the starting point of the original distance, was always an approximate distance. It was determined from available starting points depending on the venue. In 1908, the first Games given to London, the British royal family requested that the start of the marathon must be at Windsor Castle. This was to allow the royal family to witness the start of the race. The distance from the Windsor Castle to the Olympic Stadium was 42195 meters (26 miles and 385 yards) and in 1924 this distance became the standardized length of a marathon (Mallon & Buchanan, 2000:5)

To be able to compare results between different meetings and to be able to establish records, it became necessary to have standards for all the different races. All tracks had to use the same events and the same measured distances. Originally the British maintained the yard and pound as standards while the rest of the world used the meter and kilogram as standards. Since the Games in 1952 all international measurements are in meters and kilograms (Wortman, 2011).

In the rules of the International Amateur Athletics Federation (IAAF) the measuring standards and methods are prescribed. With the improvement of measuring devices it is now possible to have measurements on any straight track with accuracy of 10 millimeters (IAAF Handbook, 2012-2013).

2.6 Combined event competitions

The decathlon is a combined event in athletics consisting of ten track and field events (Handbook: IAAF Rules, 2012-2013). The word decathlon is of Greek origin. Events are held over two consecutive days and the winners are determined by the combined performance in all events. The performances are judged on a points system in each event and not by the position achieved by the athletes. The decathlon was originally only open to male athletes while female athletes competed in the heptathlon (seven events). As stipulated in the 2012 publication of the IAAF rules, women started to participate in the decathlon during the 2012 Olympic Games.

Traditionally, the title of "World's Greatest Athlete" has been given to the man who wins the decathlon. This began when King Gustav V of Sweden told Jim Thorpe, "You, sir, are the world's greatest athlete." After Thorpe won the decathlon at the Stockholm Olympics in 1912 (Trkal, 2003:12), the event developed from the ancient pentathlon. Pentathlon competitions were held at the ancient Greek Olympics. Pentathlons involved five disciplines – long jump, discus throw, javelin throw, sprint and a wrestling match. Introduced in Olympia during 708 BC, the competition was extremely popular for many centuries. By the 6th century BC, pentathlons had become part of religious games. The Amateur Athletic Union held "all around events" from the 1880s and a decathlon first appeared on the Olympic athletics program at the 1904 Games (IOC website - st-louis-1904-summer-olympics).

The scoring tables for the decathlon have undergone continual evolution since their inception about a century ago, with several changes to both the character of the equations and the indices on which the equations are based (Trkal, 2009:11)

All of the earliest attempts at formalizing decathlon scoring, from the first formal submission (prepared by the U.S. in 1884) until 1915, involved linear scoring equations. The American model was based on world records, but models concurrently used by several Nordic countries were based on their respective national records (Trkal, 2009:11)

The decathlon was first included in the Olympic Games in 1912, requiring a uniform standard. The first Olympic tables adopted were also linear functions; they were based on the 1908 Olympic records for each of the individual events. The tables were soon updated with the 1912 Olympic records. These tables were used in the next four Olympiads. The rapid evolution of the scoring tables caused results to vary widely. For instance, Akilles Järvinen, the silver medalist in the decathlon in both the 1928 and 1932 Olympics, would have won gold in both years under later years' scoring tables (Trkal, 2009:13).

To standardize the scoring tables, the IAAF, at a meeting of the technical subcommittee during the 1920 Olympic Games, decided to use the following criteria for a legitimate decathlon scoring table (IAAF News files):

- The table should reflect the fact that, at higher levels of performance, a unit gain (such as a decrement of 0,01 second in sprint times) is more significant than at lower levels of performance, because of the physiological limitations of the human body.

- The scores for different events should be comparable, in a manner such that equal skill levels in different events are rewarded with equal point levels.

In 1934, the IAAF adopted a new set of scoring tables proposed by Suomen Urheiluliitto (the Finnish athletics federation). These tables had already been used for a few years in national competitions in Finland. This scoring system implemented vast changes, with the following features (IAAF News files):

- All of the individual events were scored with exponential functions, rather than the linear functions that had characterized all decathlon scoring tables to date. For field events, this was a straightforward statistical procedure; for track events, the inverse of the athlete's time (speed) was used as the independent variable.

- The tables ranged from 0 to 1150 points per event. Zero points corresponded to the performances of untrained school children, and 1000 point performances corresponded closely to world records.

After World War II, the Finnish and Swedish athletics federations joined forces to draft scoring tables appropriate for Olympic athletes' improved postwar performances. All of the tables remained progressive in nature; in fact, the progressive character of every one of the ten tables increased. In the years following the implementation of the 1950 tables, controversy arose in regard to the highly progressive character of the tables. The tables allowed an athlete with exceptional performance in a single event and good (but not necessarily winning) performances in all other events to outperform athletes with all round good performances. To remedy this problem, Axel Jörbeck, of the Swedish athletic federation, proposed new tables that will be regressive in throwing events, while retaining their progressive character in track events. His theory to promote these tables was based on the relation between kinetic energy imparted to a throwing implement and the square of its initial velocity. He maintained that a progressive or even linear table caused unfairly large increments in the score for throwing events (Rosenbaum, 2009:12).

By the early 1980s, more problems had been pointed out with the then-current scoring tables. Specifically, the regressive nature of Jörbeck's tables for the field events seemed to discourage athletes in those events. The recorded performances in field events had improved to the point where further score increments were practically negligible. It not only reduced the motivation to improve in field events but also gave an unfair advantage to competitors in the track events (Rosenbaum, 2009:12).

The IAAF working committee therefore met in 1983 in Prague to develop improved tables, putting forth the following nine principles, which still stand today (IAAF News files):

The new tables should be one of the following:

- Modified versions of the existing ones,
- Linear in all events, or
- Slightly progressive in all events.
- The tables should be applicable to all levels of performance, from youth to elite.
- Men and women should have different tables.
- Specialists' performances should be the basis for the scores in the tables.
- The new tables should be applicable now and in the future.
- The total scores using the new tables for the top world-class athletes should remain approximately the same (about 8500 points).
- As far as possible, the new tables should ensure that a specialist in one event cannot overcome top performances in the other events.

The 1984 tables are still in use today, with a slight update in 1998 (adding entries for the long throws for odd numbers of centimeters, which were rounded to the next-lower multiples of 2 cm until 1997). Even with all the considerations used, the decathlon tables do not reflect event performances of individual athletes not participating in the decathlon. Tim Watt, in an e-mail reply to Bill Rowan (Friday 12th June 1998 at 00:24:58), commented on these tables by pointing out that the IAAF ranking gives a top score in an event where a world record was easily beaten. In contrast the steeple chase, walks, 100 meter hurdles and decathlon events are not correctly scored. He concludes with “So don't expect the IAAF tables to settle too many arguments.”

2.7 Comparative tables

Comparative tables should be able to compare the performances in different events to be able to determine the ranking of athletes across event and gender barriers. Various tables have been proposed, mostly focused on senior athletes and a few include the age groups 17 and 19 years. No international tables are available for school level.

2.7.1 IAAF Scoring tables (previously Hungarian tables)

These tables were created as an extension of the decathlon tables to cover all Olympic track and field events. These tables are only available for senior athletes and provide a point score in the range 1 to 1400 points. The latest update was done in 2011 and it is available on the IAAF website (www.iaaf.org). Most of the work done in developing these tables was through the IAAF working committee under the guidance of Dr Bojidar Spiriev (1932 - 2010). Dr Spiriev (from Bulgaria) passed away in 2010 and his work for the IAAF is carried on by his son, Attila Spiriev. These tables are currently the only tables with international acceptance. The formulae to generate the tables are

- Track events: *Points = A.(B – P)*^{C}
- Field events: *Points = A.(P – B)*^{C}

In the formulae *P* is the performance of the athlete. *A*, *B*, and *C* are constants which are practically determined and they are different for all events.

Typical constants used in the 2011 revision of these tables are as in table 2.1 (Handbook: IAAF Scoring Tables 2012-2013, Author's Introduction: VI).

Table 2.1: 2011 IAAF table constants

Gender	Event	A	B	C
Men	100m	25,4347	18,00	1,81
	200m	5,8425	38,00	1,81
	110mH	5,75352	28,50	1,92
	High Jump	0,8465	75,00	1,42
	Long Jump	0,14354	220,00	1,40
	Shot Put	51,39	1,50	1,05
	Javelin Throw	10,14	7,00	1,08
Women	200m	4,99087	42,50	1,81
	800m	0,11193	254,00	1,88
	100mH	9,23076	26,70	1,835
	High Jump	1,84523	75,00	1,348
	Long Jump	0,18807	210,00	1,41
	Shot Put	56,0211	1,50	1,05
	Javelin Throw	15,9803	3,08	1,04

2.7.2 Purdy tables (Based on the Portuguese scoring tables)

The Purdy point system is calculated from a table of running performances compiled in 1936 called the Portuguese Scoring Tables. The table lists distance and velocity from 40 meters to 100 000 meters for senior events. These velocity measures are assumed to be maximum possible velocity in a straight line (Purdy, 1970:152).

These performances are arbitrarily given a Purdy point of 950. World record times in 1970 have about 1035 Purdy points. Times are calculated from the table (time = distance / velocity) by linear interpolation (Purdy, 1970:154).

Additionally, a time factor for start-up and running on a curve of a track is also added. This "Standard Calculated" time is used to generate the points for a given performance time at the same distance (Purdy, 1970:154).

Purdy uses the function:

$$P = A(T_s/T_p - B)$$

where *P* is the Purdy points, T_s is a Standard time from the tables + time factor, T_p is the Performance time to be compared and *A* and *B* are scaling factors (Purdy, 1970:158).

The values of *A* and *B* depend on the distances of the event. A sliding scale for *A* and *B* can be found by comparing the velocities of different events at 950 and 1035 point performances. A constant *k*, calculated using the formula $k = 0.0654 - 0.00258V$, is used to determine the values of *A* and *B* by using the relations $A = 85/k$ and $B = 1-950/A$ where *V* is the average velocity of T_p (Purdy, 1970:158).

These tables do not make provision for field events, hurdles, race walking or steeple chase.

2.7.3 Modified Purdy tables

In the Least Squares Model Purdy proposes an equation which he terms the "running curve" for men's world record performances (as of 1970). This makes it possible to calculate the "standard" performance instead of using the Portuguese tables. All other formulae remain the same (Purdy, 1974:224).

2.7.4 Peter Riegel's prediction formula

Peter Riegel also did research on the prediction of distance running. The formulation for his work extended the range of athletes from senior level to masters above 70 years of age. Riegel defined a value that he calls a "fatigue factor" which depends on the training, ability and age of the athlete. By using this fatigue factor (*b*) he uses the formula $x = v^{1/(1-b)}$ to predict the distance (*x*) that an athlete can run at average speed (*v*). Again this is not a comparative table but only a prediction of possible distance given the ability of the athlete (Riegel, 1981:285).

2.7.5 David F. Cameron Model

David Cameron devised a formula that will predict an athlete's time at a different distance from the known time at another distance. The model provides statistical constants for track events from 400 meters to 50 miles. He then uses these constants in two different formulas. The first formula uses the current performance, distance and distance constant to determine the athlete's conversion factor. The second formula then uses the conversion factor, new distance and new distance constant to determine the predicted performance (Kaplan, 2010:3).

Although this is not a table, it can be used to find, for a specific athlete, predictions of comparable performances for different track events.

2.7.6 Molvar Conversion tables

The Molvar Conversion tables were devised by John Molvar. It is also a prediction system that try to convert the performance in one track event to a performance in another track event. These are perhaps the simplest ways of equating performances. The conversion is simply done by multiplying the event time by the conversion factor.

Table 2.2: Example from Molvar's conversions

100 - 200	0,500
200 - 400	0,455
400 - 800	0,635
800 - 1000	0,768

Although this is a simple conversion table, it cannot be applied to all performances in an event (Kaplan, 2010:4).

2.7.7 English High Schools tables

Tables were created by Bill Rowan to help find the best athletes for events in the English high school championships. No formula was used but rather an intuitive allocation of performances. Bill never published these tables and it was sent to Tim Watts in an e-mail dated Saturday, 6th of February 1999 at 19:49:05. The tables are extremely limited and only provide a scale from 1 to 30 points. It is also limited to the events for the age groups 17 and 19 years. Only events used during the championship are included.

2.7.8 Apple, SASOL, ABSA, ASA, APE tables

These tables are unique to South Africa and initially developed for a specific type of meeting. The names used for the tables changed according to the sponsor of the printed version of the tables. This is in accordance with an agreement between ASA and the sponsor. The names of the tables are not linked to the content in the tables or the formulation of the tables. In 1985 ASA approached the author to modify the linear tables, based on the IAAF tables. The formula was then changed from linear to logarithmic. These tables had unique constants for each event but did provide smooth transitions between age groups.

Statistical data and comments were obtained from Richard Stander (ASA). The interaction between Richard and the author took place at informal meetings where prototype tables were presented and modifications were suggested. Final drafts were circulated to various coaches for final comments before publication. The tables include all events approved by ASA for all ages from 6 years to senior level. At present these are the only tables available for school ages below 17 years and the research in this document is building on the work the author had done to publish the existing tables. Although approved by ASA and recognized by SASSA, it is not achieving the requirement of correctly comparing events at all levels. In an effort to get event difference comparison, a complex function is used.

2.8 Best performance measurement

In spite of the existence of an official scoring table this is seldom used to determine the best performances in athletics. This places doubt on the validity of the IAAF tables as the IAAF itself rarely refer to its own official tables. The IAAF only use the tables for combined event competitions and never publish table scores with the results of individual performances. The IAAF also never refer to the tables in determining a series winner in individual events. They only use the medal winning criteria for these awards.

The IAAF and most countries publish best performance lists by event. Enthusiasts then use these lists and start arguments by comparing different athletes that rank high in individual lists. They often refer to the consistency of performances and world records in their arguments to choose between athletes as the best performer. If the tables are used as a reference, people quite often reject the arguments by pointing out inconsistencies in the tables. A large number of coaches simply reject all references to tables and only use the ranking lists published by countries and the IAAF. These types of arguments have been observed during meetings at all levels over more than 30 years of experience.

When standards are set for athletes to qualify for inclusion in a team, time and distance requirements are used and never table score requirements. In most cases this method is acceptable if the size of the team is not limited by the number of athletes in the team. ASA and provinces publish the qualifying standards for specific meetings and athletes must participate during the selection period, achieving the required standards, for inclusion in a team. ASA publish A and B standards for inclusion in the South African team for the Olympics. A qualifiers will be automatically included while B qualifiers may be included if the team size permits more athletes than the automatic qualifiers. These qualifying standards can be obtained from the provincial administrators and from ASA. In some cases these standards are published on the corresponding websites.

At school level teams are normally selected by including a specific number of athletes per event. In such cases tables will make no difference to the selection. If however a team is limited to a specific number of athletes, the selection becomes more performance based and requires a different method of selection. A valid table will assist selectors to include only those athletes which perform at the highest level.

2.9 Scoring systems

Determining the winner of a specific event is normally obvious by comparing the times or distances achieved by athletes. In field events some arguments may arise if the officials are not consistent with the marking of implement landing positions. During some meetings races are run in two or more heats without a final and the winner is determined by time placement. When handheld stopwatches are used this may also cause arguments about the final placing of athletes.

To determine a winning team different methods, as explained below, are used.

2.9.1 Medal scoring system

In this method, used at all Olympic Games, the team with the most gold medals is ranked first. If two or more teams have the same number of gold medals, then the team with the most silver medals will be ranked first. If there is still no result, the team with the most bronze medals will be placed first. After this a tie is declared (Handbook: IAAF Rules 2012-2013).

The argument against this method is that actual performance is not rewarded as the difference between a gold or silver medal can sometimes be less than 0,01 of a second in a track event or a millimetre in a field event.

2.9.2 Point scoring system

In this method the athletes in each event earn points according to the placing in the event. A popular system, used by a large number of schools, is the 7-5-3-2-1 point system. Each winner earns 7 points for the team down to 5th position with 1 team point. The team with the highest total score is declared the winner. The particular scoring system used during a meeting is normally published in the program of the meeting. In some cases, where bigger athlete participation is encouraged, a dual system is used. In the Mpumalanga Inter High meetings each school enters an A and B team. The A team contributes to the 7-5-3-2-1 system and the B team contributes to a different lower scoring system of 5-3-2-1 points. The rules for the meeting are set by ASA in accordance with the IAAF Rules but the scoring system is agreed on between the participating schools and published in the program of the specific meeting. The specific system in use (7-5-3-2-1, 5-4-3-2-1, 4-3-2-1 and anything else) is totally at the discretion of the organizers of the meeting.

Again, this seems acceptable but performances are not rewarded correctly.

Some variations are used by adding bonus points for athletes that break or equal the existing records. Although this may appear to be well founded, it has some negative aspects. In the case of a new event (changes in implements or distances) there are no current records and the winning time/distance will be recorded as the new record. Must this be rewarded with bonus points? Another complication is if, on the day of the meeting, a strong wind is in the favour of track events. Most likely a large number of records will be broken but not recognized. Should these athletes be rewarded with bonus points? These personal observations and questions can be used to strengthen the argument to base results on a table scoring system rather than a point scoring system.

2.9.3 Table scoring system

In 1972 Athletics South Africa (ASA) approved a unique type of meeting between schools. A boys' team consisted of 16 athletes and a girls' team of 14 athletes. For boys the age groups were 15, 17 and 19 years, and for girls it was 14, 16 and 18 years. A school could enter just boys, just girls or both as these were separate competitions during the same meeting. Each athlete was allowed a maximum of two events. For boys the best 16 results and for girls the best 12 results were used as the team result. This required a table similar to the IAAF tables as athletes were participating in different events. Medals and point scores were irrelevant to the team scores. A linear table was created based on a simplified version of the IAAF tables and modified for the required age groups. These tables were initially known as the Apple tables (sponsored by Ceres) and soon changed to SASOL tables when SASOL took over the sponsorship of this meeting. The full history of the development of these earlier tables can be found on the internet (Bekker Sport website). This type of meeting became very popular between schools with different variations such as TOP 10 (10 athletes per team), TOP 15 and more. The popularity of these meetings can be attributed to the smaller teams involved which reduce transport cost and give exposure to top athletes at more regular meetings against other top ranking athletes.

2.10 Victor and Victrix Ludorum

Victor Ludorum is Latin for "the winner of the games" (Oxford English dictionary). The Oxford English dictionary expands with the following interpretation “a boy or man who is the overall champion in a sports competition, especially at a school or college”. It is usually a trophy presented to the most successful competitor at a sports event. It is presented to the athlete who has won the most events or who has accumulated the most points (using a point system) through competing in many events. Female competitors compete for the Victrix Ludorum. The specific criteria (points, table scores or medals) for these trophies are determined by the organizers of each meeting and sometimes also published in the program of the meeting. There are no specific prescriptions from IAAF or ASA as to the way in which such a trophy must be determined. In friendly meetings between schools no trophies or scores are used.

The flaw in the point or medal method of awarding these trophies is clear if the following example is considered. In a specific age group an athlete gets 1st place in all four events with moderate results because of very little competition in this age group. This athlete does not qualify for the provincial team. In another age group two athletes get two 1st and two 2nd places each but both qualify for the provincial team and compete in the finals at the SA championship meeting. According to the point or medal system the first athlete will be declared the Victor Ludorum. Clearly the other two athletes are the better performers and one of them should have been declared the Victor Ludorum. If a table were used this would have been the case.

The winner of this trophy must not be confused with the person who has accumulated the most medals or who has participated in a larger number of events than prescribed by the IAAF and ASA rules for a competition.

The winner of this trophy must also be distinguished from the winner of a combined event competition such as the pentathlon (7 events) or octathlon (8 events) where the number of events exceed the requirement for standard track and field meetings.

Because of IAAF and ASA limitations on the number of events that an individual athlete may participate in during a specific meeting, this reward is normally calculated on the best 3 or 4 results of an athlete. Most schools use the point system to determine these awards. The limitation on participation is regulated by the South African Schools Sport Association (SASSA) and is enforced to protect athletes from over-participation. The specific limitation is meeting dependent and published on the entry regulations for each meeting. To illustrate the reasoning used to determine the limitation consider the following two types of meetings:

Meeting 1 is held between two schools only and it is concluded in one day. In this case the number of participants in any specific event will be low and only finals will be available in all events. Athletes can participate in up to 4 different events and with a good spread of events all athletes should have sufficient recovery time between events.

Meeting 2 is a national championship with a large number of entries. Most track events will require a quarter final, followed by a semi-final and then a final. The event is held over two consecutive days. A track athlete can then face 3 races in each event entered resulting in up to 12 races. This is prevented by limiting athletes to 3 events and thus a maximum of 9 races over the 2 day period.

As each meeting has different parameters of time and total number of events, the organizers of the meeting have the responsibility of limiting the number of entries by any specific athlete. This is published in the entry regulations for each specific meeting.

2.11 Factors to consider in creating a table

2.11.1 Influence of training

While the author attended a coaches' training session in Potchefstroom, Dr Tim Noakes made a statement based on his research and experience. He said that if any homogeneous age group and gender is tested over any arbitrary distance, the times recorded will display a normal distribution curve. If this group is then trained and retested, the distribution curve base will be narrowed and the average will be an improved time. The order of athlete placing will however remain the same. From this he concluded that natural athletes come from a 0,05% of the population and any person outside this group will never be able to win a natural athlete, even with the best training.

Dr Noakes continued that the human is inherently "lazy" but seeks recognition. This recognition is achieved by an internal motivation to perform in a particular aspect of his or her life. For the high performance athletes this recognition is the winner podium and a medal.

Dr Noakes further explained that this clarifies the progression of athletes from shorter to longer distances. The 100 meter race requires the least training and the natural athletes can afford to be "lazy" and still be rewarded for his or her ability to perform. When he or she starts to be outside the medal performances in some races, the will to perform acts as an inherent motivation to train more and shift to longer distances where there are fewer natural athletes.

This is also confirmed by the performances of Bruce Fordyce. He followed an intensive training schedule and won the Comrades marathon nine times from 1981 to 1990 (Bloomberg interview, 2005). During this time he attempted the "shorter" distances of 5000 and 10000 meter. While officiating during meetings held at the Wanderers, Krugersdorp and Herman Immelman (Germiston) the author observed that Bruce, in all these attempts, never received a track medal.

2.11.2 Track and equipment development

The modern athletics track is a far cry from the original open space tracks. There are still grass and gravel surfaces at a large number of venues but most championship meetings are held on synthetic tracks. The surface will have an influence on the friction and grip and this will influence the eventual time of the race. The development of tables cannot consider a track surface factor as it would be difficult to measure the surface coefficient, and performances on the best available tracks should be the norm (Zumerchick, 1997:301).

Equipment and running aids have also improved and this, together with improved training techniques, contributes to the improvement of records. In 2006 the IAAF had to change the specifications of javelins. They ruled that the center of gravity must be shifted forward by about 20 centimetres to allow the javelin to dip faster. This was done because top athletes started to achieve distances exceeding the size of the javelin area (Handbook: IAAF Rules, 2012-2013).

Considering the above it is clear that tables will have a life cycle and that adjustments on individual events may be required at regular intervals.

2.11.3 Height above sea level

Air pressure has an effect on the available oxygen levels in a person's lungs and the impact forces with the track during a race. This will again influence the reaction times and maximum speed of a runner. Adjustments must be included based on experimental values obtained from measured differences (Hackett, 2007) The influence on the performance of field events exists but it is so small that it can be neglected for these events. The official adjustments are available in the published tables.

2.11.4 Wind resistance

Any moving object causes wind resistance. Factors like the shape, surface area and clothing material will all have an influence on the measure of resistance. It is also found that the wind profile on a 100 meter track is varying according to the surrounding structures. As it is currently not possible to measure the effect on each individual athlete, the current ruling is that wind measurements will only be recorded for record purposes. In rules 163.8 to 163.13 the IAAF explains how wind measurements must be taken (Handbook: IAAF Rules, 2012-2013). To be able to compare results the measured wind speed must be displayed with the race time. Wind assisted performances in all races up to 200 meters, long jump and triple jump will not be considered if the assisting wind speed exceeds 2 meters per second (Rule 260.22 (d)). For all longer races, it is considered that the wind will assist the athlete for some sections of the race and work against the athlete in other sections (Ward-Smith, 1985:351).

2.11.5 Reaction times of timekeepers

Where handheld stopwatches are used the difference between these times and electronic timing is attributed to the hand-eye reaction times of the timekeepers. This time will depend on the distance between the timekeepers and the starter. On a standard oval track the current acceptable differences are specified in the IAAF Rules. These adjustments only apply to races up to 400 meters. The current adjustments are 0,14 seconds for races starting on the track side closest to the timekeepers (60 to 110 meters and 400 meters) and 0,24 seconds for all other distances (Handbook: IAAF Rules, 2012-2013).

2.12 IAAF Competition rules

In all events changes in rules, implements, measuring requirements and prescribed techniques must be considered when measuring performance. In some cases a rule change can influence the actual performance levels of participating athletes and such changes will thus also influence any comparative measurements. A complete document of the IAAF 2012-2013 rules with highlighted changes can be viewed in the attachment “IAAF Rules 2012-2013.docx”.

2.13 Summary

It is clear that a large number of conflicting situations and arguments can be resolved if a valid and acceptable table system is used to compare performances. Unfortunately the current available tables are not based on the most acceptable statistics and do not reflect performance improvement correctly. This clearly indicates the need for a thorough research using statistical information from past events and considering all other influencing factors to formulate a performance comparison table that will be acceptable to the athletics community.

In the next chapter the data will be analysed and mathematical models will be developed based on the data. The current systems will be considered and criticism on these systems will be explained.

Chapter 3: Review of current systems

Although the research will concentrate on South African school data it is essential to start analysing the available world statistics. It will ensure that the modelling results can be compared to existing models for validation. To ensure that the models proposed are reputable, they must be based on verifiable data. Various factors must be considered before data can be regarded as acceptable.

3.1 Introduction

The requirements for the recognition of records, as prescribed by the IAAF and ASA, according to the IAAF Handbook of Rules 2012-2013, are:

- All officials at the specific event must be qualified by ASA in that event.
- All timing of track events must be done using electronic timing equipment.
- Wind measurements must be taken for all track events up to a distance of 200 meters as well as for long jump and triple jump.
- All field equipment must be certified as correct within the limits of the IAAF Rules.

The reality is that the author has observed that most meetings lower than provincial level and even some provincial meetings don't meet most of these requirements. Unqualified teachers and parents are used as officials, hand timing is mostly used and wind readings are rarely available. The lack of equipment needed for the recognition of results can be attributed to the cost of constructing a suitable track, the cost of electronic timing equipment and insufficient staff members qualified in athletic officiating. This implies that all results at school meetings must be regarded as suspicious and “record” information is only used as performance markers without credibility.

The most reliable data available are from meetings directly controlled by the IAAF. This will therefore be used to formulate the models and then reputable South African data will be used to validate the models.

The factors that must be considered in the modelling will be different for the different types of events:

- For track events the athlete relies on physical fitness, speed, speed endurance, reaction times and blood oxygen content. The distance of the race will determine the prominent factor.

- In the case of long jump and triple jump, technique and the effect of gravity must be considered as well as the transfer of vertical speed to horizontal speed while maintaining the vertical component.

- In the high jump explosive power in converting vertical speed to horizontal speed while controlling the centre of gravity during the jump, is considered.

- For all other field events the transfer of body energy to kinetic energy in the implement at the point of release is the main technique to be considered. The distance achieved by the implement is then controlled by the laws of gravity.

Considering the above, different models will be used for the different types of events while maintaining the comparison levels between the models. This implies that different case studies will be considered and a relation between the cases will be established. Obviously, in all events, other factors such as the frictional force of the specific track and the individual athlete, body weight and length of the athlete, stride length and psychological condition of the athlete also affect the performance at a particular meeting but, as these factors are not considered during a meeting, they will also not be considered in the formulation of the cases.

3.2 Delimitations

The data used in the analysis and verification of results will be limited to those available up to the 2012 athletic season.

Although the final findings will be applied to South African schools track and field athletics, most of the derivations will be based on data obtained from world senior athletics.

At junior level data was used from world junior athletics (athletes not older than 19 years of age), world youth athletics (athletes not older than 17 years of age) and South African championship meetings. No results from provincial or school meetings were used in derivations but these are referred to in the verification of formulations.

The justification of this is based on the availability of sufficient reliable and verifiable data. All the data used was published from results obtained during meetings sanctioned by either the IAAF or a member country affiliated to the IAAF. The South African data used was only from the national championship meetings sanctioned by ASA (affiliated to the IAAF). At these meetings all officials must be qualified to judge, measure and record the results of athletes correctly (Handbook: IAAF Rules, 2012-2013).

3.3 Case considerations

All the tables used or suggested to date just provide a relationship between performances within an event and different unrelated tables are used for the different events. Most tables used the same formula for all events but each event has its own unique set of constants determined from practical values. The only tables that try to relate events equally are those developed by the working committee of the IAAF for the combined events (Decathlon, Octathlon, Heptathlon and Pentathlon). The complete IAAF tables used for all track and field events used the same formula but different constants. This also applies to similar events. If the published IAAF tables are inspected it can be seen that in the 100 meter race for men there are different sets of constants for the same event in the Decathlon table and the full table. This is also observed for all the other corresponding events in the combined event tables.

The following four relations will be considered in the development of the cases:

- A formulation for the relationship between different events within an age group. This is the first sub-objective.
- A formulation for the relation within an event for different age groups. This is the second sub-objective.
- A formulation for the difference between male and female athletes in similar events. This is the third sub-objective.
- A formulation for the performances rewards within an event. This is the main objective of the research.

The first three were not considered in any of the existing tables and no reference to such relations was found in any existing references to tables.

3.4 Overview of current tables

Before any new formulations can be done it is necessary to consider the work done by other researchers/groups to formulate performance measurements.

3.4.1 IAAF tables

A full discussion of the development of these tables will be given as this is currently the only tables recognized for track and field athletics. The tables originated with the revival of the modern combined events competitions. It probably started in America about 1880 and scoring was carried out using a table prepared for the American Athletic Union. During first the Decathlon it included 100 yards, shot put, high jump, 880 yards walk, 16 lb hammer throw, pole vault, 120 yards hurdles, 56 lb weight throw, long jump and 1 mile run. It proved so popular that the organizers of the 3rd Olympic Games in St. Louis in 1904 arranged for a Decathlon to take place in conjunction with the Games, though not as an official event (Durant, 1973:7).

Similar experiments with Pentathlons and Decathlons were introduced throughout Scandinavia and in Germany. At the Olympic Games in Athens in 1906, Greece made an attempt to revive the classical Pentathlon with a standing long jump, ancient style discus throw, javelin throw, 192 meter sprint and wrestling, but combined events, for track and field only, had now progressed to a point that any other event was excluded. The Decathlon, with its good balance of track, jumping and throwing events requiring both explosive and endurance qualities, was developing a unique group of followers (Durant, 1973:9).

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By 1910 Sweden, who was to stage the 5th Olympic Games in Stockholm in 1912, had decided to include a one day Pentathlon (long jump, javelin throw, 200m, discus throw and 1500m) as well as a two day Decathlon (100m, long jump, shot put, high jump, 400m, 110m hurdles, discus throw, pole vault, javelin and 1500m). This sequence of events was confirmed at the 1914 IAAF Congress and has remained unchanged to this day. The Pentathlon has also remained unchanged except for a change in the scoring method in 1928. Until then, the scoring was based on the addition of the place number in each event; the lowest total winning. After 1924, the Pentathlon was dropped from the Olympic Games since the inclusion of two men's combined events was considered excessive. The Pentathlon continues as an official IAAF event, in particular for one day meetings, in club competitions and as a team event (Durant, 1973:12).

All the early tables were linear and it only required two points on the graph. The top value (national/world records) and the bottom value (the time for walking the distance) were used to define the tables. The most prominent of these early men's tables were as shown in table 3.1 (Durant, 1973:14).

Table 3.1: Early tables used at the Olympic Games (1884 to 1911)

Date	Country	Type	Top	Comments
1884	USA	Linear	1000	World records
1901	Denmark	Linear	1000	National records revised in 1910
1902	Sweden	Linear	1000	National records (Malmö Tables)
1909	Finland	Linear	1000	National records
1911	Germany	Linear	1000	World records for the 1912 Olympic Games

From 1911 onwards, the main interest for all international men's combined events competitions lies in the series of tables prepared initially for the Olympic Games and later for the IAAF. National federations and individual persons, however, continued to prepare new sets of tables some of which were eventually adopted by the IAAF. Others, such as the "Portuguese Tables" of 1949/1954/1962, acquired an excellent world reputation and some others served to develop the art and science of scoring tables (Trkal, 2009:3).

From 1920, three concepts became prominent in the theory and development of scoring tables. These have, in varying degrees, influenced all subsequent tables. These concepts are:

- The fact that to continuously improve the performance in an event, requires a progressive effort from the athlete. This will eventually lead to the maximum performance possible. The resulting scoring table that will reflect this effort is progressive but, applied simply, this leads to an exceedingly progressive scoring table and the main challenge has been to control this excess.

- The need to be able to compare the performance of an athlete in one event with that of another athlete in a different event.

- The wish to have a really "scientific" basis for any scoring system. With the growing research into human physiology and sports science, it seemed possible that a basis could be found in physiological parameters, such as heart beat, breathing rate and oxygen uptake or oxygen depletion and so on. The interplay of these and other interests in the development of the scoring tables over the past 65 years is a fascinating study.

The new scoring tables were calculated by J. Ohls from Finland in 1931. These tables were progressive and corresponded to the formula $P = f\ (e^M)$, where P is the score, e is the base of natural logarithms and M corresponds to the performances. The tables reflected integer points for performances measured to 0,01 second intervals on the track. The 1000 point value was near the then world records. The tables were calculated up to 1150 points.

The new scoring table was such a success when introduced in 1932 in Finland that it was adopted by the IAAF at its next Congress in 1934. The main difference consisted in the progressive character of the Finnish evaluation as against the linear evaluation of decathlons at the Olympic Games in 1936 and at the European Championships in 1938, 1946 and 1950 (Trkal, 2009:5).

In the latter part of the 1970's, pressure began to mount for a revision of the scoring tables. This arose for two reasons. First, all previous sets of IAAF scoring tables were intended to carry out two functions: to provide a scoring system for combined events competitions and to provide a method of comparing performances by different athletes in different events. Secondly, following the basic physics of the Ulbricht principles, all the tables for track events were progressive, whereas all the tables for field events were regressive (Trkal, 2009:11).

The effect of the dual use for the tables is that the scores for individual event world records should be approximately equal. The best single event performances in world record class combined events are bound to be less good and to a widely different degree, owing to the differences between a single event performance and the same performance set in the pressure of a combined events competition. As a result, the best scores set in each individual event will vary widely.

Technically, this does not matter at all if the differences in the scores between different athletes in one event are roughly proportional to the differences in their performances, but the emotional effect on the athletes could be very severe. The effect of the regressive scoring tables in the field events has become important, as the range of performances in combined events has widened with the great improvement in the top class performances. There comes a point with a regressive scoring table when it does not seem worth while trying any harder in that event, with a diminishing yield in points for each improvement in performance.

The IAAF Technical Committee Working Group (Robert Blanchet, Carl-Gustav Tollemar, Viktor Trkal and Etienne Wante) under the leadership of Emmanuel Rose, Technical Committee Chairman, met in Prague on March 2 and 3 1983 with observers from FRG, GDR, USA and several statisticians. Nine points were accepted as basic principles for a new set of tables (Trkal, 2009:7).

- The new set of tables should be used for combined events only.

- Results in various events should, as far as possible, yield about the same number of points if the results are comparable as to quality and difficulty.

- The new tables should be either:

  A modification of the existing ones OR
  A straight line in all events OR
  Slightly progressive tables in all events.

- It must be possible to use the scoring tables for beginners, juniors and top athletes as well.

- There will be a specific scoring table for men and another table for women.

- All the new versions of the scoring tables should be based on the statistical data for the combined events by paying due regard to the statistical data for performances by athletes participating in a single event.

- The new tables should be applicable now and for the future.

- It is desirable, without creating other problems, that the total scores using the new tables for the top world class athletes should remain approximately the same i.e. is about 8500 points for the decathlon and about 6500 points for the heptathlon.

- As far as possible the new tables must insure that a specialist in one event cannot overcome performances in the other events.

Fulfilling all these conditions was not easy. Particularly the requirement to maintain 8500 point totals for the decathlon. This will require that any change in points in one event should be reflected in all the other events. The option to develop a slightly progressive table for all events was chosen.

Since the 1984 Scoring Tables apply only to combined events competitions, the best individual event performances in combined events can score roughly the same number of points. With the abandonment of the Ulbricht principles, the disadvantages of the regressive tables for field events have been avoided.

With the extension of the tables to include all events, the requirement to maintain the current total points for the Decathlon at 8500 points caused the development of separate tables for normal track and field meetings and combined events. With the increased popularity of indoor athletics and considering the smaller track, a third set of standards are used to create the IAAF tables for indoor meetings. This requirement however places some doubt on the integrity of both tables.

The existing tables are generated using the formulae:

Track events: $P = a.(b - T)^c$. Where *T* is Time in seconds.
Jump events: $P = a.(M - b)^c$. Where *M* is a measurement in centimetres.
Throwing events: $P = a.(D - b)^c$. Where *D* is the distance in meters.

The values of *a*, *b* and *c* are event specific constants.

Note: The value of *P* (points) must be rounded down to a whole number after calculation (Integer values) (Introduction to the IAAF Scoring Tables).

A comparison between the values of combined events and those of the full tables shows the following differences for the 100 meter and long jump events (Table 3.2).

Table 3.2: Comparing IAAF full tables and combined event tables

100m		
Time	Full	Decathlon
10.40	1072	999
10.41	1069	996
10.42	1066	994
10.43	1063	992
10.44	1059	989
10.45	1056	987
10.46	1053	985
10.47	1050	982
10.48	1047	980
10.49	1043	977
10.50	1040	975

Long jump		
Distance	Full	Decathlon
7.76	1075	1000
7.75	1073	997
7.74	1071	995
7.73	1069	992
7.72	1067	990
7.71	1065	987
7.70	1063	985
7.69	1061	982
7.68	1058	980
7.67	1056	977
7.66	1054	975

Similar differences exist for all the other events.

As these tables are the most widely accepted in the athletic community, it is necessary to investigate the observed problems in these tables. The progressive nature of the tables are obvious when considering the figures 3.1

to 3.16. The events are grouped in logical units and scores are used at the 100 point intervals of the tables.

The data in the tables are extracts from the current IAAF tables available in the annexure "IAAF scoring tables.xls" which was extracted from the published tables in the annexure "IAAF Scoring Tables of Athletics - Outdoor.pdf" and available online at the IAAF website.

To ensure that the basis of the research and the formulations are complete, the progressive nature of all events in the only tables currently accepted, is included in the following tables and figures.

Table 3.3: IAAF values for Men sprints and middle distances

IAAF - Men - Sprint and Middle distance								
Points	**100 m**	**200 m**	**400 m**	**800 m**	**1500 m**	**3000 m**	**5000 m**	**10000 m**
1400	9.46	18.90	41.75	97.65	199.44	425.53	730.09	1515.44
1300	9.74	19.50	43.18	100.79	206.19	440.61	755.92	1574.90
1200	10.02	20.13	44.66	104.05	213.20	456.28	782.75	1636.70
1100	10.32	20.78	46.21	107.46	220.52	472.61	810.73	1701.12
1000	10.63	21.47	47.83	111.02	228.17	489.71	840.02	1768.55
900	10.96	22.19	49.53	114.76	236.22	507.69	870.81	1839.44
800	11.30	22.95	51.33	118.72	244.73	526.69	903.36	1914.39
700	11.67	23.76	53.24	122.94	253.79	546.93	938.02	1994.19
600	12.07	24.63	55.30	127.47	263.52	568.67	975.26	2079.93
500	12.49	25.57	57.54	132.39	274.10	592.31	1015.75	2173.16
400	12.97	26.62	60.02	137.84	285.81	618.46	1060.54	2276.29
300	13.51	27.81	62.83	144.02	299.10	648.14	1111.37	2393.35
200	14.15	29.22	66.16	151.36	314.86	683.34	1171.68	2532.19
100	14.98	31.06	70.51	160.92	335.40	729.23	1250.27	2713.14

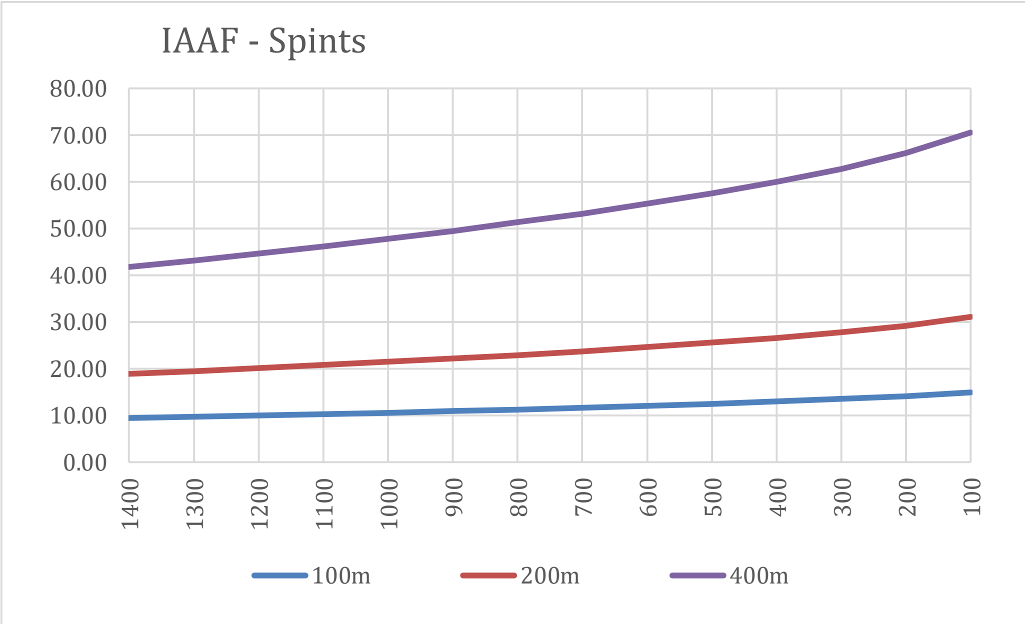

Figure 3.1: Progressive indicator for IAAF tables – Men Sprints

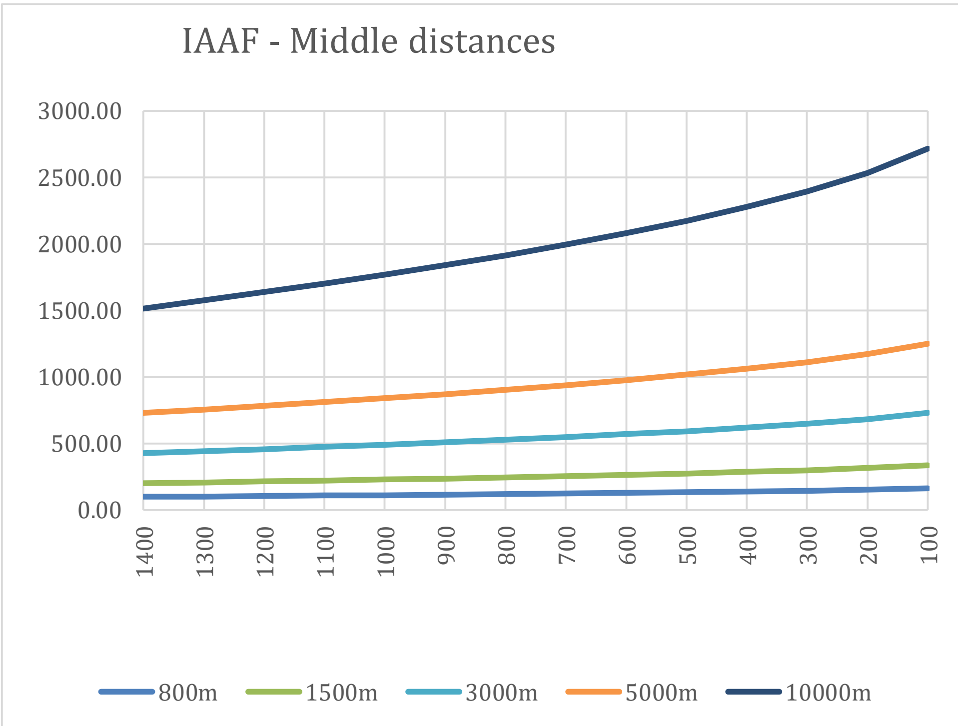

Figure 3.2: Progressive indicator for IAAF tables – Men Middle distances

Table 3.4: IAAF values for Men hurdles and Steeple Chase

IAAF - Men Hurdles and Steeple Chase				
Points	**110m H**	**400m H**	**2000m SC**	**3000m SC**
1400	12.26	44.57	290.06	450.46
1300	12.76	46.47	303.52	471.17
1200	13.28	48.45	317.50	492.70
1100	13.82	50.52	332.08	515.15
1000	14.38	52.68	347.34	538.65
900	14.98	54.96	363.39	563.35
800	15.61	57.36	380.35	589.46
700	16.28	59.92	398.41	617.27
600	17.00	62.67	417.82	647.14
500	17.78	65.66	438.92	679.63
400	18.65	68.97	462.26	715.56
300	19.63	72.72	488.75	756.35
200	20.80	77.18	520.17	804.73
100	22.32	82.98	561.13	867.78

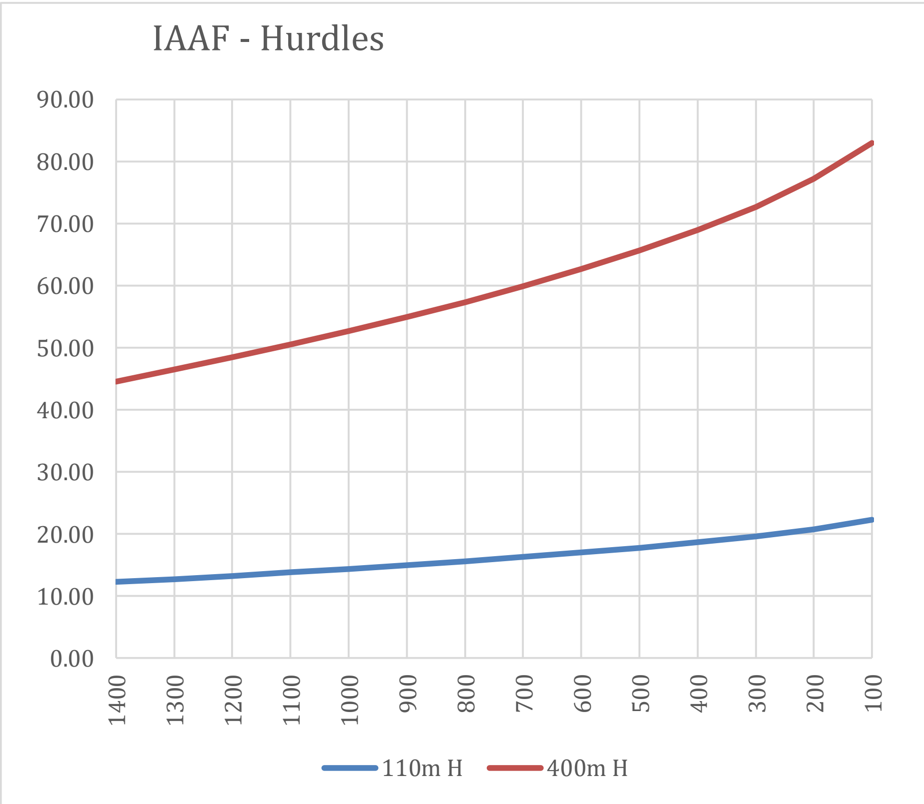

Figure 3.3: Progressive indicator for IAAF tables – Men Hurdles

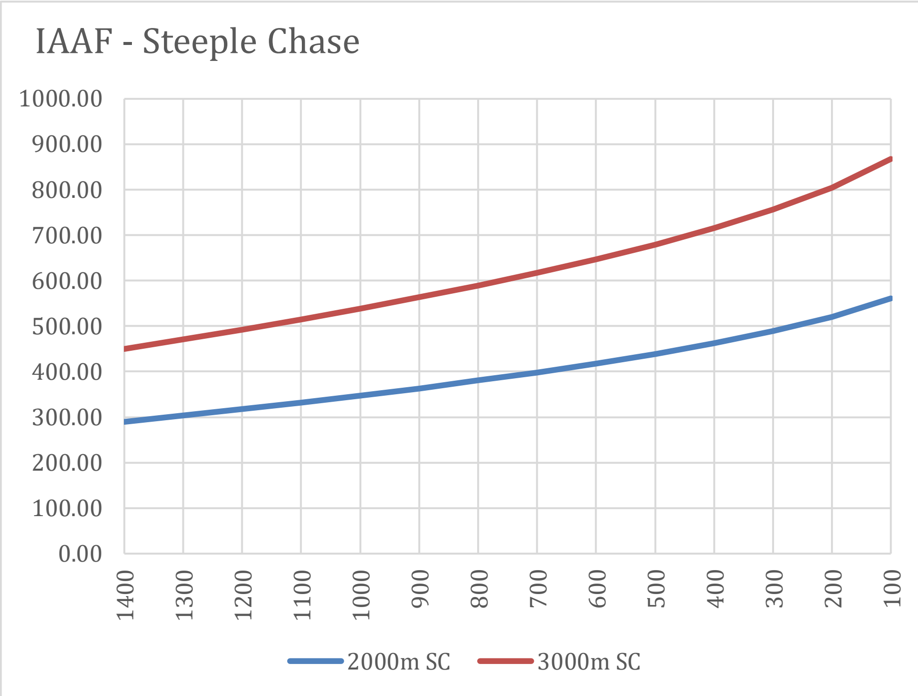

Figure 3.4: Progressive indicator for IAAF tables – Men Steeple Chase

Table 3.5: IAAF values for Men race walking and relays

IAAF - Men – Race Walking and Relays							
Points	**3kmW**	**5kmW**	**10kmW**	**20kmW**	**4x100m**	**4x200m**	**4x400m**
1400	566.00	957.00	2028.00	4215.00	35.87	75.42	167.04
1300	609.00	1029.00	2166.00	4498.00	37.11	77.91	172.89
1200	655.00	1104.00	2309.00	4792.00	38.40	80.50	178.98
1100	702.00	1182.00	2459.00	5099.00	39.74	83.21	185.32
1000	751.00	1264.00	2615.00	5420.00	41.15	86.03	191.96
900	803.00	1350.00	2780.00	5758.00	42.63	89.01	198.94
800	857.00	1441.00	2954.00	6115.00	44.20	92.15	206.32
700	916.00	1537.00	3139.00	6495.00	45.86	95.50	214.18
600	978.00	1641.00	3338.00	6903.00	47.65	99.10	222.62
500	1046.00	1754.00	3554.00	7347.00	49.60	103.01	231.81
400	1121.00	1880.00	3793.00	7838.00	51.75	107.34	241.96
300	1207.00	2022.00	4064.00	8396.00	54.20	112.25	253.49
200	1308.00	2190.00	4387.00	9057.00	57.10	118.07	267.16
100	1440.00	2410.00	4806.00	9919.00	60.87	125.67	284.98

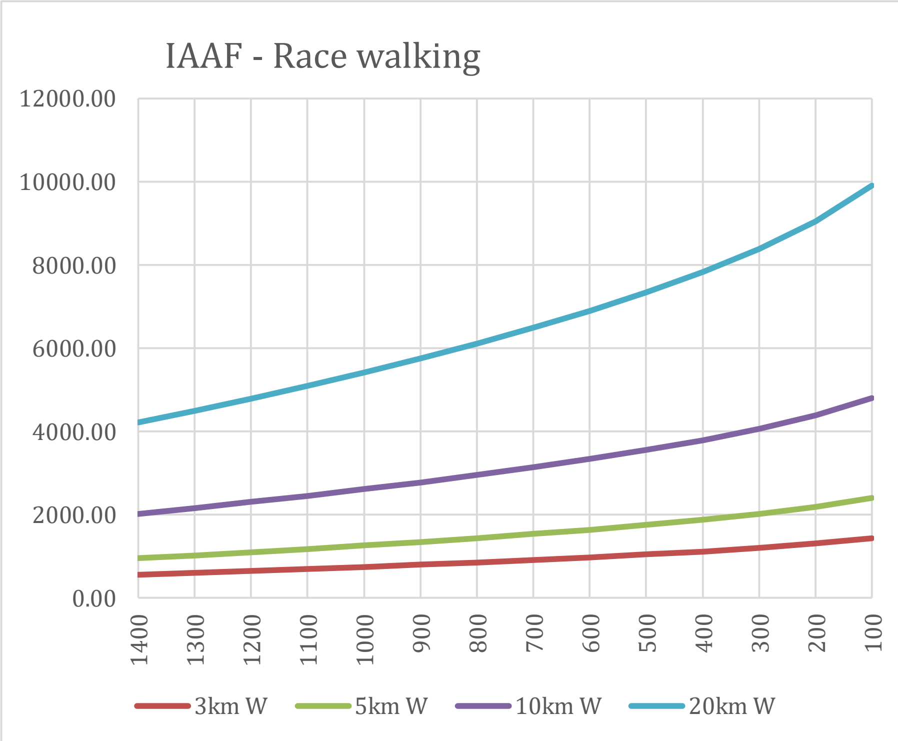

Figure 3.5: Progressive indicator for IAAF tables – Men Race walking

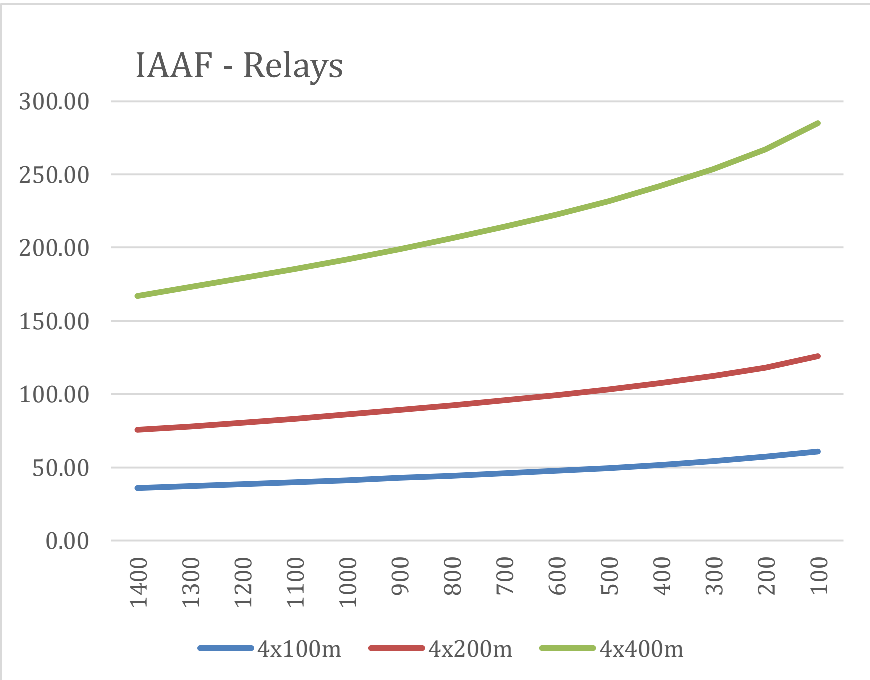

Figure 3.6: Progressive indicator for IAAF tables – Men Relays

Table 3.6: IAAF values for Men field events

IAAF - Men - Field events								
Points	**HJ**	**PV**	**LJ**	**TJ**	**SP**	**DT**	**HT**	**JT**
1400	2.55	6.51	9.29	19.23	24.66	78.73	94.11	102.24
1300	2.45	6.16	8.82	18.32	22.99	73.30	87.59	95.16
1200	2.34	5.81	8.35	17.41	21.32	67.86	81.06	88.05
1100	2.23	5.45	7.88	16.49	19.65	62.40	74.51	80.93
1000	2.12	5.09	7.40	15.56	17.97	56.93	67.94	73.80
900	2.02	4.72	6.92	14.63	16.29	51.45	61.36	66.64
800	1.90	4.36	6.44	13.68	14.60	45.96	54.76	59.47
700	1.79	3.99	5.95	12.73	12.91	40.45	48.15	52.29
600	1.69	3.62	5.46	11.77	11.22	34.92	41.52	45.08
500	1.57	3.24	4.96	10.80	9.52	29.39	34.88	37.86
400	1.45	2.86	4.46	9.83	7.81	23.84	28.22	30.62
300	1.34	2.48	3.95	8.84	6.11	18.28	21.54	23.36
200	1.22	2.09	3.44	7.85	4.40	12.70	14.84	16.09
100	1.10	1.70	2.92	6.84	2.68	7.11	8.13	8.79

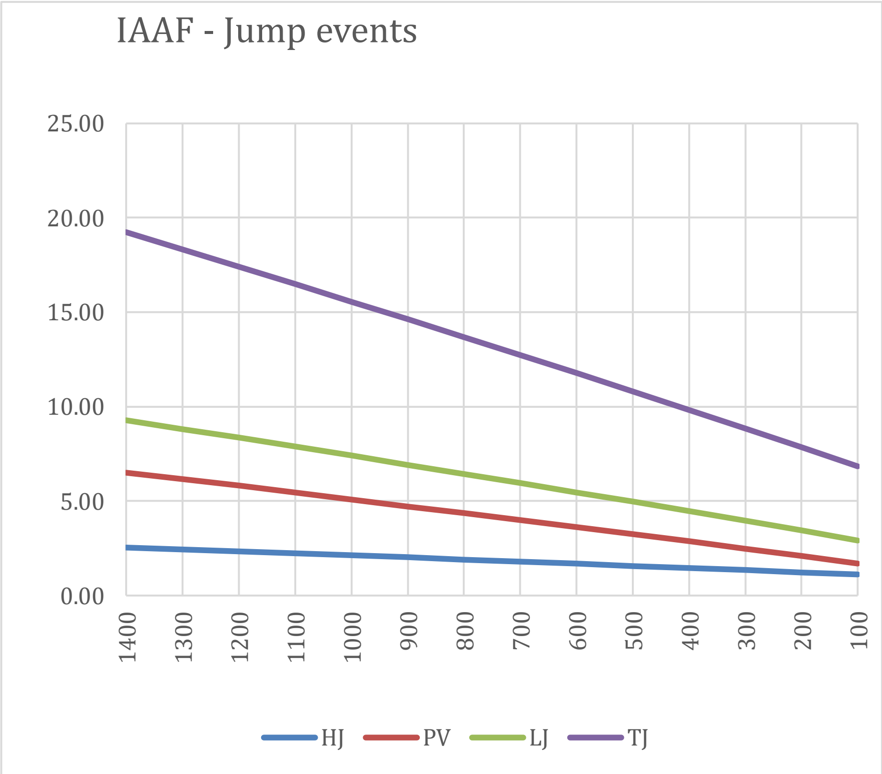

Figure 3.7: Progressive indicator for IAAF tables – Men Jumps

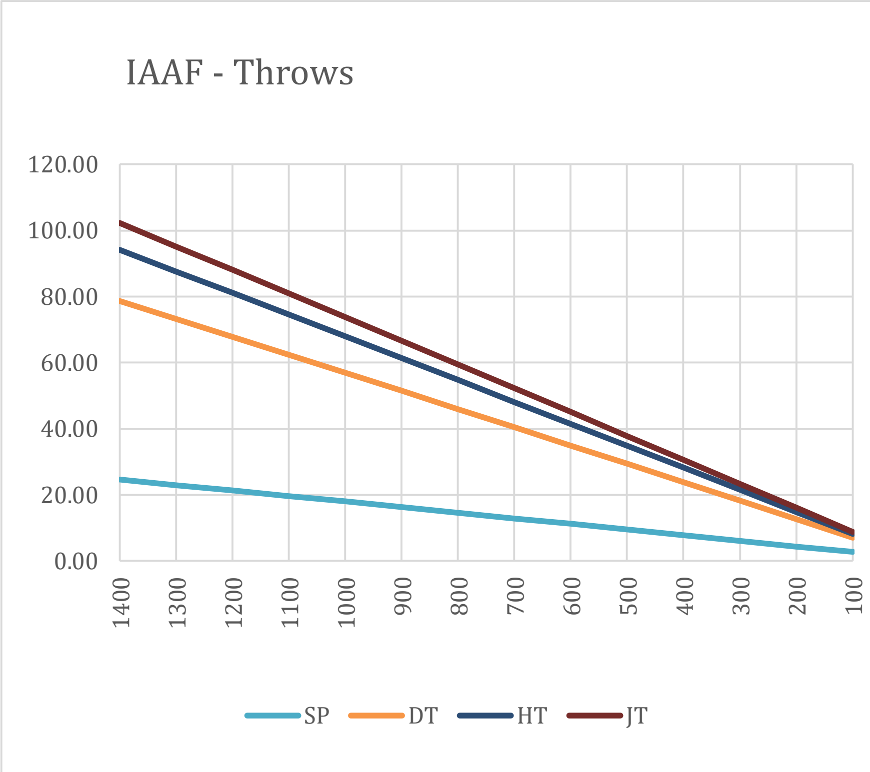

Figure 3.8: Progressive indicator for IAAF tables – Men Throws

Table 3.7: IAAF values for Women sprints and middle distances

IAAF - Women - Sprints and Middle distances								
Points	**100m**	**200m**	**400m**	**800m**	**1500m**	**3000m**	**5000m**	**10000m**
1400	9.98	20.16	44.72	106.78	216.77	457.43	783.68	1640.35
1300	10.47	21.23	47.35	111.99	228.52	484.44	831.57	1744.37
1200	10.98	22.34	50.08	117.41	240.74	512.52	881.33	1852.48
1100	11.52	23.49	52.93	123.05	253.48	541.78	933.21	1965.19
1000	12.07	24.70	55.91	128.96	266.82	572.42	987.51	2083.15
900	12.66	25.98	59.04	135.17	280.83	604.62	1044.60	2207.18
800	13.28	27.32	62.36	141.74	295.66	638.67	1104.96	2338.31
700	13.94	28.75	65.89	148.73	311.44	674.92	1169.22	2477.92
600	14.65	30.29	69.68	156.24	328.39	713.87	1238.27	2627.92
500	15.42	31.96	73.80	164.41	346.83	756.23	1313.35	2791.03
400	16.27	33.82	78.36	173.44	367.22	803.08	1396.40	2971.45
300	17.24	35.92	83.54	183.70	390.37	856.26	1490.66	3176.24
200	18.39	38.41	89.68	195.87	417.83	919.33	1602.48	3419.15
100	19.88	41.66	97.68	211.72	453.61	1001.54	1748.20	3605.72

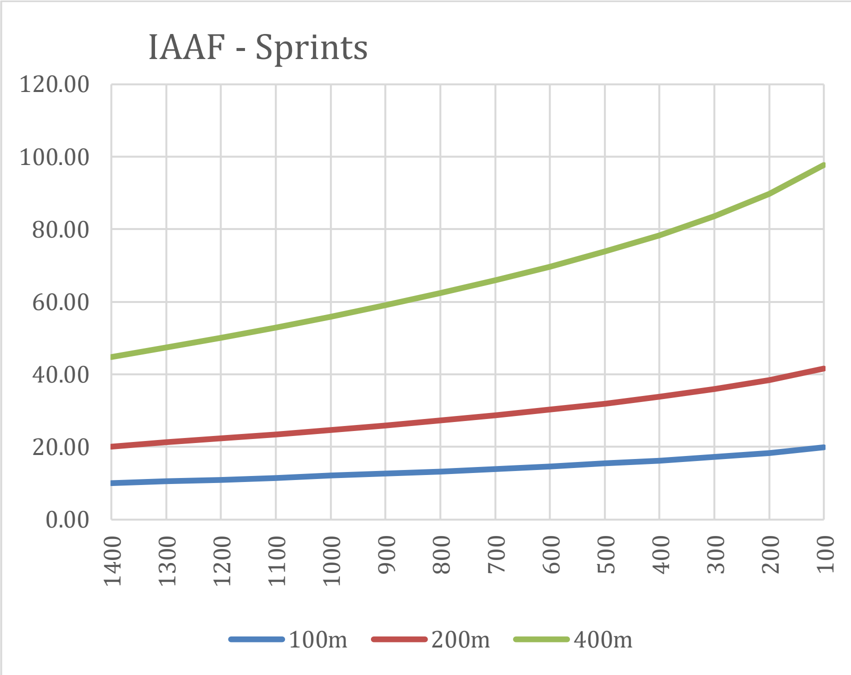

Figure 3.9: Progressive indicator for IAAF tables – Women Sprints

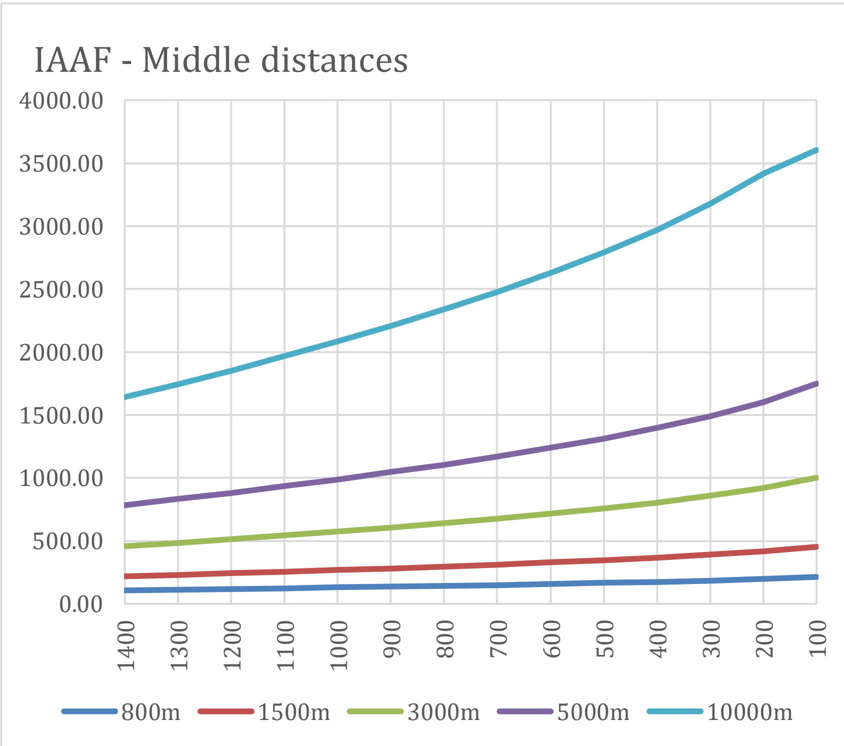

Figure 3. 10: Progressive indicator for IAAF tables – Women Middle distances

Table 3.8: IAAF values for Women hurdles and Steeple Chase

IAAF - Women - Hurdles and Steeple Chase				
Points	**100mH**	**400mH**	**2000m SC**	**3000m SC**
1400	11.12	48.07	322.22	481.31
1300	11.86	51.05	342.51	518.73
1200	12.63	54.14	363.60	557.61
1100	13.43	57.37	385.58	598.16
1000	14.26	60.75	408.59	640.59
900	15.14	64.31	432.78	685.21
800	16.07	68.06	458.36	732.38
700	17.06	72.06	485.59	782.60
600	18.12	76.36	514.85	836.56
500	19.28	81.03	546.66	895.24
400	20.56	86.20	581.85	960.14
300	22.01	92.07	621.80	1033.80
200	23.73	99.03	669.18	1121.19
100	25.98	108.10	730.92	1235.07

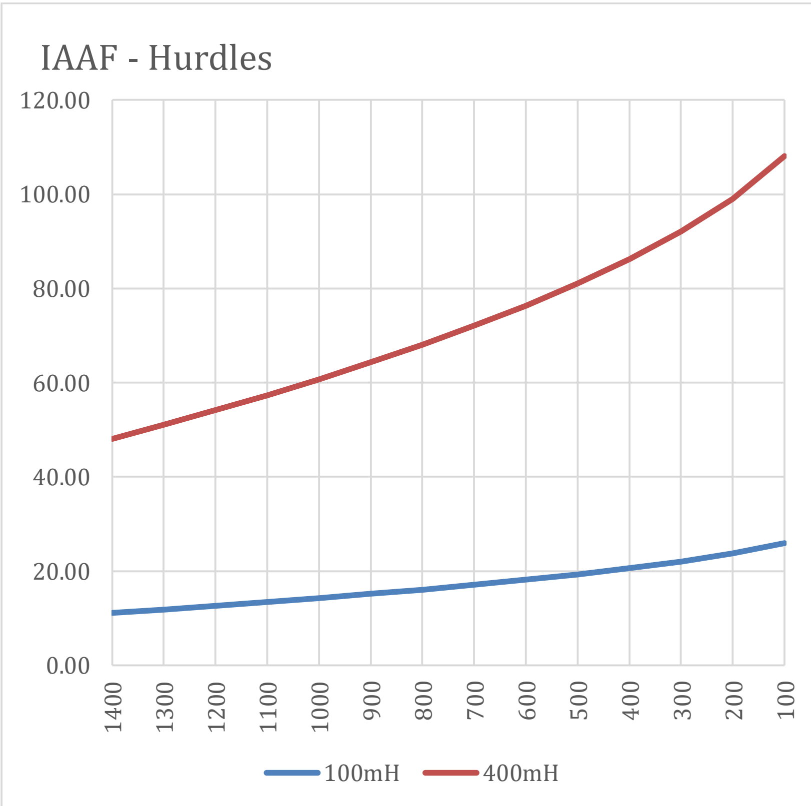

Figure 3.11 – Progressive indicator for IAAF tables – Women Hurdles

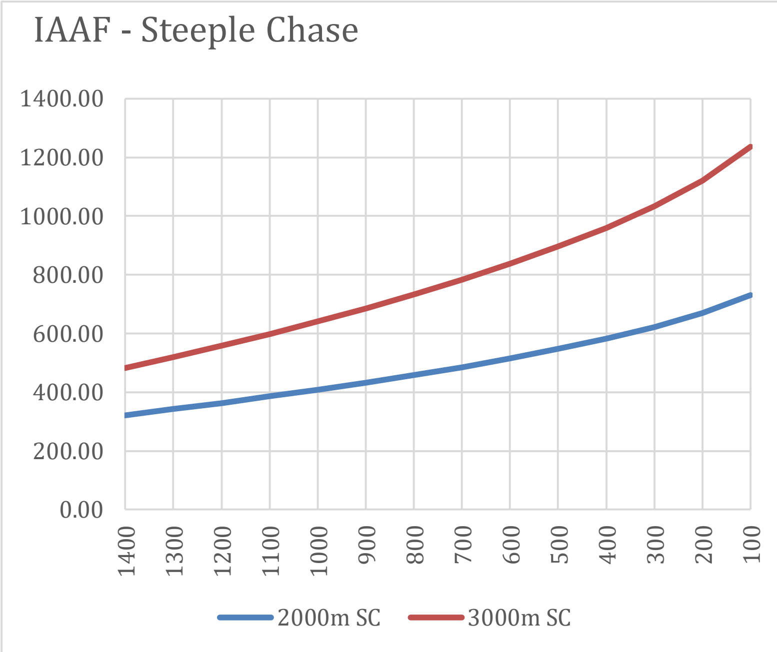

Figure 3.12: Progressive indicator for IAAF tables – Women Steeple Chase

Table 3.9: IAAF values for Women race walking and relays

IAAF - Women – Race Walking and Relays							
Points	**3km W**	**5km W**	**10km W**	**20km W**	**4x100m**	**4x200m**	**4x400m**
1400	587	1024	2119	4384	38.31	79.29	180.61
1300	646	1122	2319	4792	40.48	84.12	191.50
1200	708	1224	2527	5216	42.74	89.14	202.82
1100	772	1330	2743	5658	45.09	94.37	214.62
1000	840	1441	2970	6121	47.55	99.84	226.97
900	910	1558	3209	6607	50.14	105.60	239.96
800	985	1682	3461	7121	52.88	111.68	253.68
700	1065	1814	3729	7669	55.79	118.16	268.30
600	1151	1955	4018	8257	58.92	125.12	284.00
500	1244	2109	4331	8897	62.33	132.69	301.08
400	1347	2279	4678	9605	66.09	141.06	319.97
300	1464	2472	5072	10408	70.37	150.57	341.41
200	1602	2701	5539	11360	75.44	161.84	366.84
100	1783	2999	6148	12602	82.04	176.53	399.98

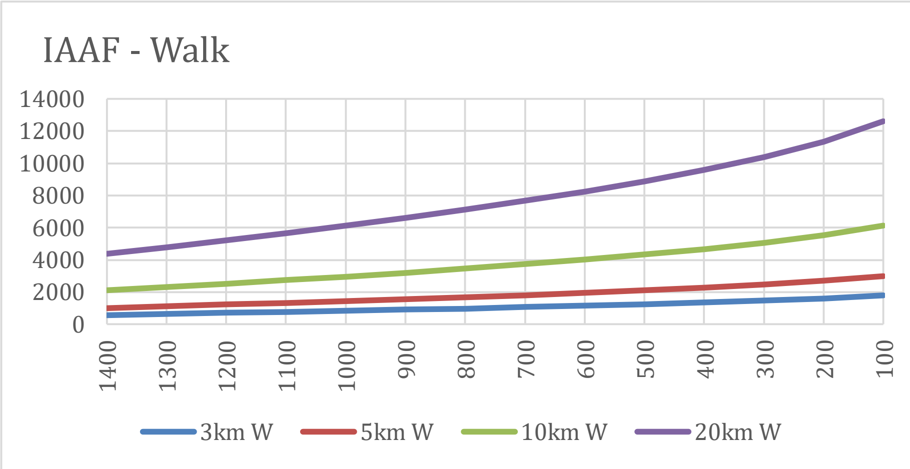

Figure 3.13: Progressive indicator for IAAF tables – Women Walk

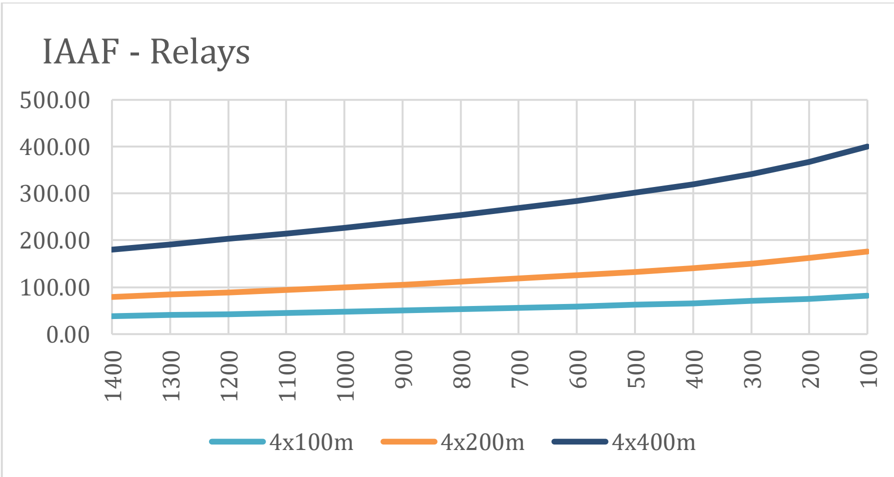

Figure 3.14: Progressive indicator for IAAF tables – Women Relays

Table 3.10: IAAF values for Women field events

IAAF - Women - Field events								
Points	**HJ**	**PV**	**LJ**	**TJ**	**SP**	**DT**	**HT**	**JT**
1400	2.20	5.46	7.89	16.86	23.67	77.74	88.89	78.75
1300	2.10	5.15	7.44	15.93	22.04	72.35	82.74	73.28
1200	2.00	4.83	6.98	14.98	20.40	66.95	76.58	67.81
1100	1.90	4.51	6.53	14.03	18.76	61.53	70.40	62.32
1000	1.80	4.19	6.06	13.07	17.11	56.10	64.20	56.82
900	1.70	3.86	5.60	12.11	15.46	50.66	58.00	51.31
800	1.60	3.53	5.12	11.13	13.81	45.20	51.77	45.78
700	1.50	3.20	4.65	10.15	12.15	39.73	45.54	40.24
600	1.40	2.87	4.17	9.16	10.49	34.25	39.28	34.69
500	1.29	2.53	3.69	8.15	8.82	28.75	33.01	29.12
400	1.19	2.19	3.20	7.14	7.15	23.24	26.73	23.54
300	1.08	1.85	2.71	6.12	5.48	17.72	20.43	17.94
200	0.97	1.51	2.21	5.09	3.80	12.18	14.12	12.34
100	0.86	1.16	1.71	4.05	2.12	6.63	7.79	6.71

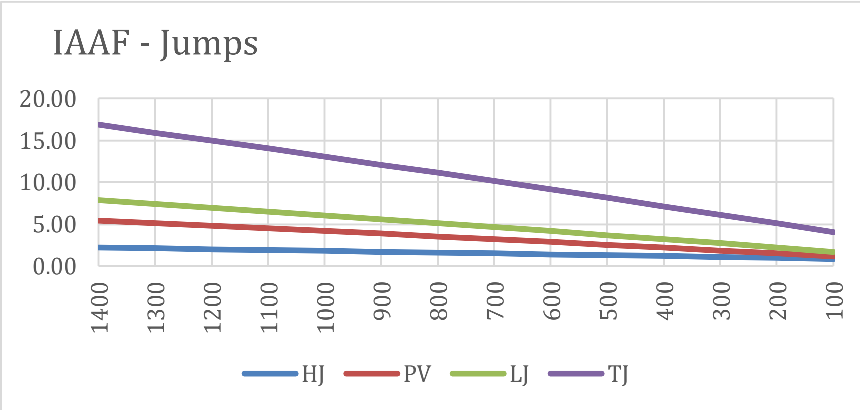

Figure 3.15: Progressive indicator for IAAF tables – Women Jumps

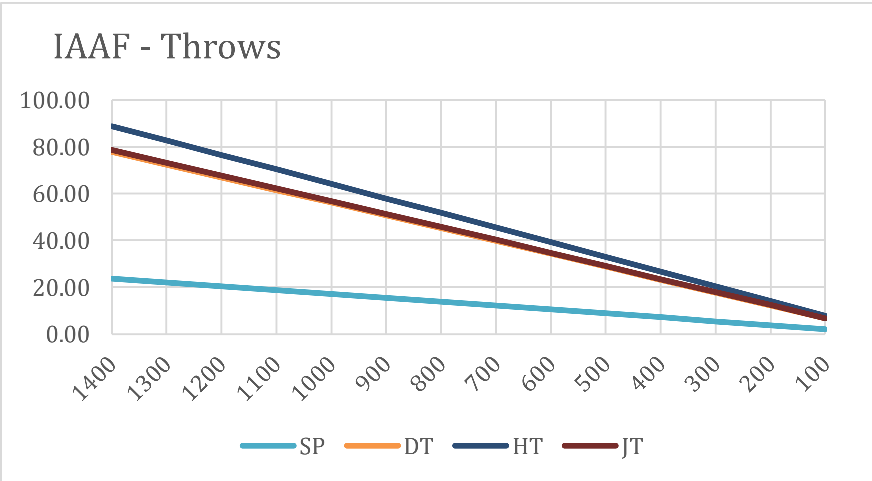

Figure 3.16 – Progressive indicator for IAAF tables – Women Throws

A graphical difference between all tables will be given after the discussions of the other available tables.

All track events are obviously progressive and reward performance increases correctly. This is not obvious for the field events. A slight progressiveness can be observed if the full range is considered.

A bigger problem is observed if the track events are normalized. This is done by dividing the performances by the relative distance, giving the time per 100 meter for all track events. This relation was calculated from the previous tables and displayed in Figure 3.17.

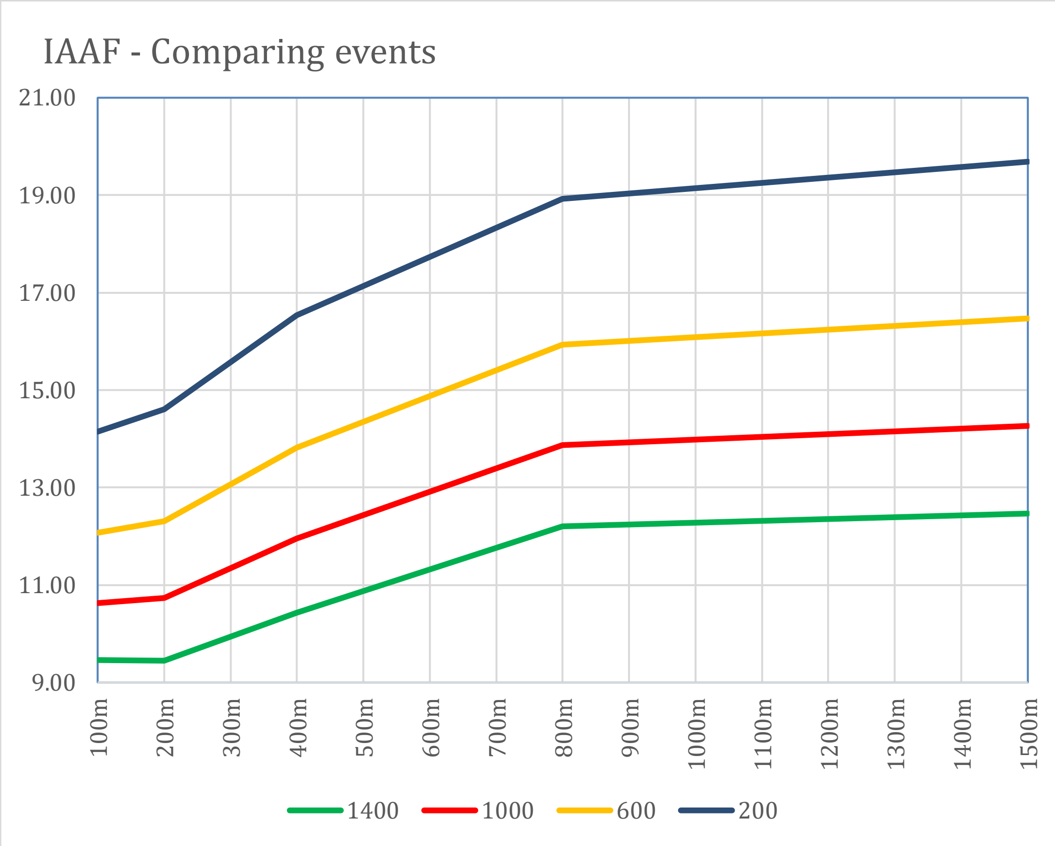

Figure 3.17: Comparing IAAF tables – Different normalized men track events

To obtain a linear scale non-events (300, 500, 600, 700, 900 meter and all the distances between 1000m and 1500 meter) are added in. On this scale a smooth progression would be expected between events and the same curve should exist at all score marks.

If the 100 meter performance is projected to all other sprints at the 1400 point level then the results are highlighting the relation problem between events in Table 3.11.

Table 3.11: IAAF track events with same 1400 point performances

IAAF - Men - Sprint and Middle distance								
Points	**100m**	**200m**	**400m**	**800m**	**1500m**	**3000m**	**5000m**	**10000m**
1400	9.46	9.46	9.46	9.46	9.46	9.46	9.46	9.46
1200	10.02	10.08	10.12	10.08	10.11	10.14	10.14	10.22
1000	**10.63**	**10.75**	**10.84**	**10.76**	**10.82**	**10.89**	**10.88**	**11.04**
800	11.30	11.49	11.63	11.50	11.61	11.71	11.71	11.95
600	12.07	12.33	12.53	12.35	12.50	12.64	12.64	12.98
400	12.97	13.32	13.60	13.35	13.56	13.75	13.74	14.21
200	14.15	14.63	14.99	14.66	14.93	15.19	15.18	15.81

At the 1000 point level an 800 meter athlete should run a faster time than a 400 meter athlete for the same score. Similar problems can be seen from this table. The graphical representation of this data is shown in Figure 3.18.

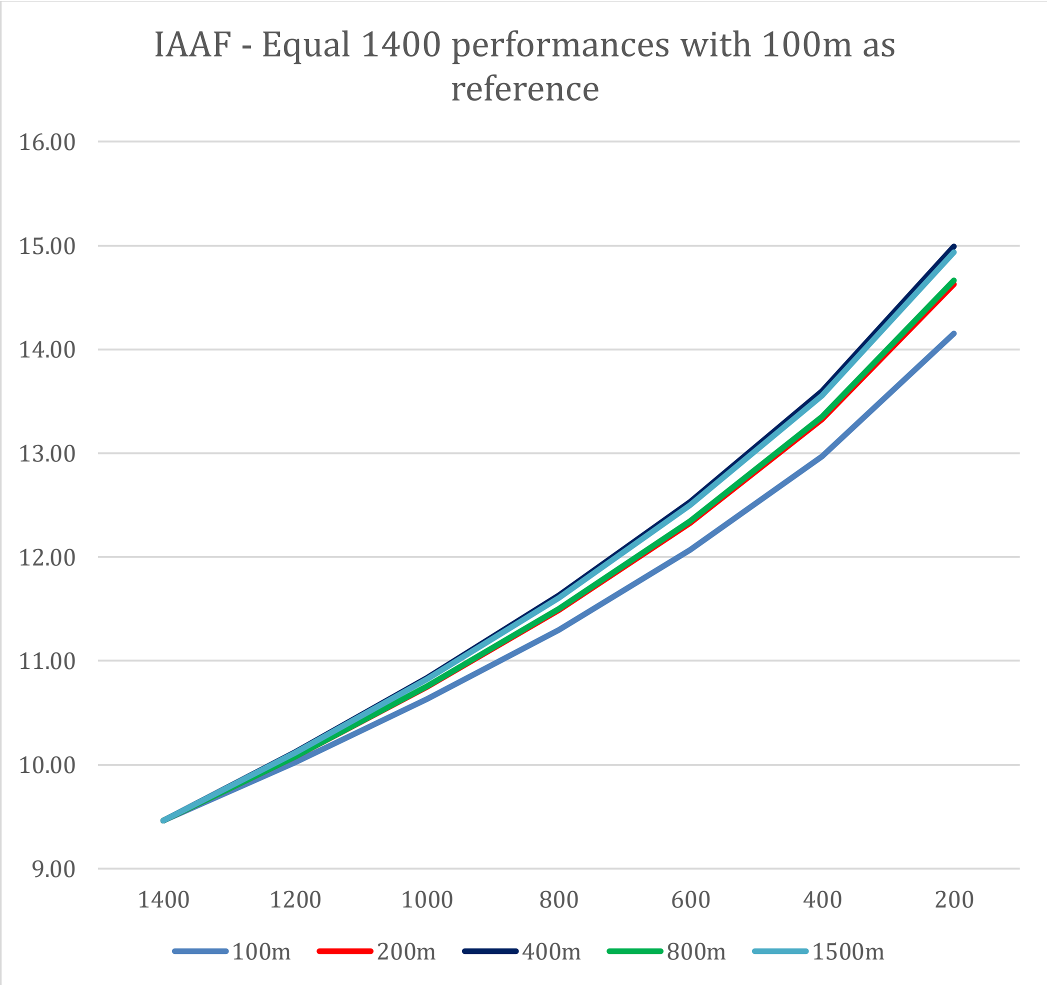

Figure 3.18: IAAF tables – Normalized men track events at 1400 points

All events should have the same shape and a progression from 100 to 10000 meter, but the order is rather: 100m, 200m, 800m, 1500m, 400m, 3000m, 5000m and then 10000m.

If the range of any event is inspected and considering that these are tables for senior men and women, then the lower end is within reach of most primary school athletes and the high end is totally outside the ability of any athlete.

The IAAF complicates things further by using different tables for the combined events. The same formulae are used but with different constants. This raises a question about the integrity of the tables. By comparing some of the decathlon tables with the full tables the following is obtained:

Table 3.12: IAAF comparing combined events and full table values

Points	Dec	Full	Dec	Full	Dec	Full	Dec	Full	Dec	Full
	100m		400m		110mH		HJ		JT	
1200	9.59	10.01	42.37	44.66	12.34	13.28	2.41	2.34	90.10	88.05
	4.20%		5.13%		7.08%		-2.99%		-2.33%	
1000	10.40	10.63	46.17	47.83	13.80	14.38	2.21	2.12	77.19	73.80
	2.16%		3.47%		4.03%		-4.25%		-4.59%	
800	11.28	11.30	50.32	51.33	15.42	15.61	2.00	1.90	64.09	59.47
	0.18%		1.97%		1.22%		-5.26%		-7.77%	
600	12.27	12.07	54.98	55.30	17.23	17.00	1.77	1.68	50.74	45.08
	-1.66%		0.58%		-1.35%		-5.36%		-12.56%	
400	13.42	12.97	60.40	60.02	19.38	18.65	1.52	1.45	37.05	30.62
	-3.47%		-0.63%		-3.91%		-4.83%		-21.00%	

The percentages are the deviations with respect to the full tables and it varies widely at all levels of the tables. At the 1000 point level the variation is from -4,59% to +4,03%. In some events the combined event standards are higher than required for normal events and in others it is lower. This is evident from the percentage deviation in the above table.

At the high end of the table the decathlon athletes must have better performances than the track athletes and at the lower end it is the opposite.

In some events the decathlon tables extend to 1520 and in other it is terminated at 1250. This can be verified from the annexure "IAAF Scoring Tables for Combined Events.pdf" published on the IAAF website.

This raises the question of which of the two official sets of tables can be regarded to correctly compare performances. As the only table used during an Olympic meeting is the combined event table, the full table must be regarded with suspicion.

3.4.2 Hungarian tables

These tables are very similar to the IAAF tables and the latest update to these tables was done in 1992. These tables are not used officially at any meeting that the author is aware of but they contributed to the establishment of the IAAF tables. These tables are still available and is often referred to for comparison arguments.

The formulas are:

- Track events: $HP = a.(b - p)^2 + C$
- Field events: $HP = a.(p - b)^2 + C$

Where: *p* = Performance of the athlete and *a*, *b* and *C* are event constants.

The difference between the Hungarian tables and the IAAF tables is that the Hungarian tables use a common progression, as indicated by the power of 2, where the IAAF tables has event dependent progression values between 0,86 and 2,01.

3.4.3 Purdy tables

The Purdy point system is calculated from a table of running performances compiled in 1936 known as the Portuguese scoring tables and they only exist for track events. The table lists distance and velocity from 40m to 100000m.

These velocity measures are assumed to be maximum possible velocity in a straight line. These performances are arbitrarily given a Purdy point of 950. Times are calculated from the table (*t=d/v*) by linear interpolation. Additionally, a time factor for start-up and running on a curve of a track is also added. This "Standard Calculated" time is used to generate the points given some performance time at the same distance.

$$P = A.(T_s/T_p - B)$$

Where P is the Purdy points,
T_s is a standard time from the tables plus a time factor,
T_p is the Performance time to be compared and
A and B are scaling factors depending on individual events.
The variables A and B are related by a constant k.

Purdy uses the following method to calculate A and B:

$k = 0{,}0654 – 0{,}00258V$

$A = 85/k$

$B = 1-950/A$ where V is the average velocity of T_p (Distance/Time).

3.4.4 Mercier tables

These tables were devised by Daniel Mercier. This is a joint project with Athletics Canada, to be used in part for the purposes of National Team selection and carding.

This is a linear table where the points are calculated using the formula

$Points = A.V + B$

Where V is the velocity of the athlete, A and B are event constants. For field events the velocity is replaced by the square root of the performance.

3.4.5 Running prediction tables

A number of persons have developed formulae that can be used to predict a performance over a certain distance from a known performance in any other distance. These are not published tables and most commonly used for longer distances. Typical examples are:

- The work done by Thomas J. Ehrensperger (1995) which is a run-pace predictor from 100m to 100km.

- The David F. Cameron Model uses a linear calculation with the mile as standard and constant multipliers to obtain predictions transferred to other distances.

- The Riegler formula predicts a distance that can be reached based on average speed and a fatigue factor.

- The Molvar Conversion tables were devised by John Molvar and it is similar to the Cameron model using multipliers to predict the times of different events.

3.4.6 Graphical comparison of the existing tables

For simplicity this comparison in Figure 3.19 will only be done on the 100 meter for men on a range from 10,74 seconds to 10,90 seconds completion times. The full range of values follows the same trend as in this limited comparisons. The same trend is also observed in all other events. It is thus considered sufficient to use this reduced section to demonstrate all comparisons.

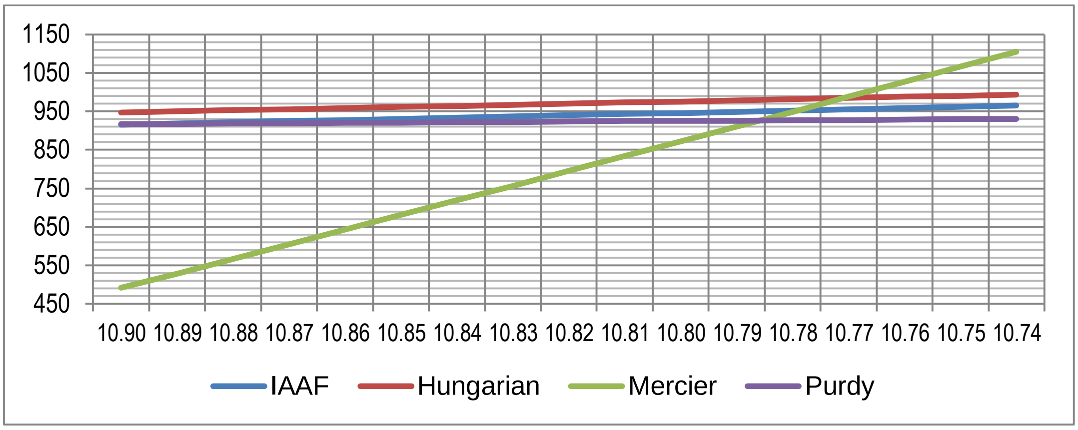

Figure 3.19: Comparing all tables for men 100 meter performances

The Mercier table gives a good resolution but is linear and only for track events. If it is removed then the other three tables produce the results in Figure 3.20.

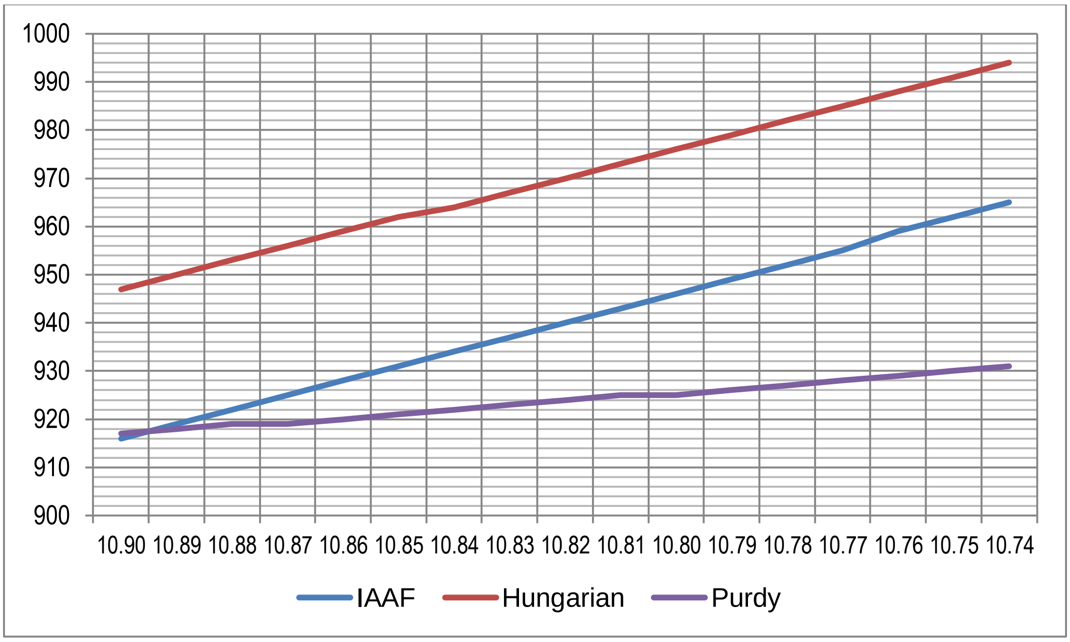

Figure 3.20: IAAF, Hungarian and Purdy for men 100 meter performances

From Figure 3.20 it is clear that the IAAF and Hungarian tables are the most acceptable (more progressive than Purdy) with similar properties and only a shift in scale.

In spite of valid criticism, it is obvious why the IAAF decided to use this format of the tables. Due to the above, all modelling and research will be done with comparison to the IAAF tables.

3.4.7 Criticism on the existing tables

The IAAF tables are the most commonly referred to and thus also the most criticized. The author has the opinion that the tables lack differentiation and does not reward performances correctly.

The lack of differentiation is evident if the 2012 London Olympic results are examined. Consider the first 10 performances in the 10 000 meter for men as listed in Table 3.13 and it is clear that the point difference at this performance level is too small.

Table 3.13: IAAF 10000m results at the 2012 Olympic Games

Olympic Games 2012					
Gender	**Event**	**Athlete**	**Rank**	**Mark**	**IAAF**
Men	10000m	FARAH Mohamed	1	27:30.42	1178
Men	10000m	BEKELE Tariku	2	27:31.43	1176
Men	10000m	BEKELE Kenenisa	3	27:32.44	1175
Men	10000m	TADESE Zersenay	4	27:33.51	1173
Men	10000m	GEBREMARIAM	5	27:36.34	1169
Men	10000m	KIPSIRO Moses Ndiema	6	27:39.22	1164
Men	10000m	LEVINS Cameron	7	27:40.68	1162
Men	10000m	MASAI Moses Ndiema	8	27:41.34	1161
Men	10000m	RITZENHEIN Dathan	9	27:45.89	1154
Men	10000m	KAJUGA Robert	10	27:56.67	1138

Analysis of the above results shows that if the athletes finished closer to each other there is the possibility that two athletes with different results could be awarded the same IAAF scores.

Further, because of this lack in differentiation, the relative merits of the table scores do not stand up to the general perception of how good the performances are. This statement implies that the tables are not sufficiently progressive at the top of the scale.

When comparing results between different events, the world record of 1:40,91, set by David Rudisha in the 800m, is only ranked 6th best for the meeting and the best field event is considered to be the 5,97m height achieved by Renaud Lavillenie in the Pole vault. This achievement is given the 22nd position in the IAAF ranking. Only 14 field events are ranked in the first 100 positions. This is an indication of a possible difference in standards between track events and field events.

There was also criticism on the level of the steeple chase event where the best performance by Mahiedine Mekhissi-Benabbad of 8:16.23 is ranked 162nd.

The Hungarian tables are very similar to the IAAF tables with an apparent shift in the table values. Otherwise the same criticism applies to these tables.

The Purdy tables display nice features of distinguishing between performances. It is however limited to track events and complicated to use as values must first be obtained from a table as input to the actual calculations. It also requires an arbitrary allocation of the 950 point mark which will make it unsuitable for event comparisons.

The linear Mercier tables are simplistic and this was already rejected by the IAAF in 1983.

All other formulae are simplistic in nature and can only be used as predictors of possible achievements.

The existing tables currently used in South Africa to score and compare events for primary and secondary schools are closely related to the IAAF tables and often criticised that standards in different events are not comparable.

3.5 Summary

From this chapter it is evident that thorough research is required to develop a new formulation for performance measurement tables that will award performances correctly, have valid comparisons between events and also extend the measurements and tables to other age groups.

Not one of the available tables or formulae (IAAF, Hungarian, Portugese, Purdy, Molvar or Regiel) meets the objectives of this study.

In chapter 4 reliable data collected will be analysed, normalised and investigated to determine possible formulae that can be used to satisfy the objectives.

Chapter 4: Data Analysis and Case Formulations

4.1 Data acquisition

Data was obtained from World rankings, South African championships, Provincial championships and school meetings. The raw data can be viewed in the attached documents. The international data is available on the website of the IAAF and a variety of other international results can be obtained from various websites.

Most of the South African data was received by e-mail and direct contacts with club and school administrators. Specifically, the secretary of the South African Schools Sports Association (SASSA), Mr Peppi Oliwano and Mr Richard Stander of Boland Athletics provided useful data.

A large number of results were only available in PDF format and this was converted to Excel format using software (PDF to Excel Converter) obtained from Blue Soft in Germany.

4.2 Data ordering

Before the data can be analysed it must be ordered by gender, age and event. Records will only be considered for range checking. It is the author's opinion that records are quite often exceptions to the rule and tend to distort the analysis. This view is supported by the fact that some world records were set more than 10 years ago. The oldest senior record is the 1:53,28 in the 800 meter for women set by Jarmila Kratochvilova on the 26th of July 1983 in München. There is thus a lack of repeatability on these performances.

To obtain a relationship between similar events in different age groups the author will be using every 5th position of the available data (5th, 10th, 20th, 25th ….) ranking positions. This will ensure a representative sample of each event's results without any cluttering of closely grouped values. The same ranking positions are used to observe trending between track events within an age group and to determine the relation between track and field events. The work done by Grubb (Grubb, 1998:501) based on senior men and women track events from 400 meter onwards uses the first 18 results in each event. This work was an attempt to find a prediction formula for future world records. Using this limitation (18 results) the 100 meter and 200 meter events were omitted as no conclusive results could be obtained.

Where implements are involved, such as hurdles, javelins and more, those events using the same implements (weights) are grouped together as sub groups of the event. Further research and modelling is required to determine the effect of different implements within the same event.

During the first phase in formulating the models, trends in each event must be determined. World rankings for the period 2007 to 2011 were used and the following tables reflect the event and available number of entries used as raw data. This data was obtained from the IAAF website and full results can be viewed in the annexure “World 2007-2011 bests.xlsx”.

Table 4.1: Top 15 (of 304) performances in Men’s 100m during 2007

Senior Men								
No	Mark	Wind	Athlete	Nation	Rank	Venue	Date	Year
1	9.74	1.7	Asafa Powell	JAM	1h2	Rieti	09/09/2007	2007
2	9.78	0.0	Asafa Powell	JAM	1	Rieti	09/09/2007	2007
3	9.83	-0.3	Asafa Powell	JAM	1	Stuttgart	22/09/2007	2007
4	9.84	-0.5	Tyson Gay	USA	1	Indianapolis, IN	22/06/2007	2007
5	9.84	-0.3	Asafa Powell	JAM	1	Bruxelles	14/09/2007	2007
6	9.85	-0.5	Tyson Gay	USA	1	Osaka	26/08/2007	2007
7	9.90	0.5	Asafa Powell	JAM	1	Roma	13/07/2007	2007
8	9.91	-0.5	Derrick Atkins	BAH	2	Osaka	26/08/2007	2007
9	9.93	0.0	Walter Dix	USA	1	Sacramento,	08/06/2007	2007
10	9.94	0.9	Asafa Powell	JAM	1r1	Oslo	15/06/2007	2007
11	9.95	0.3	Derrick Atkins	BAH	1	Athína	02/07/2007	2007
12	9.96	-0.5	Asafa Powell	JAM	3	Osaka	26/08/2007	2007
13	9.96	0.0	Wallace	USA	1	Shanghai	28/09/2007	2007
14	9.97	0.5	Asafa Powell	JAM	1r1	Beograd	29/05/2007	2007
15	9.97	-1.1	Tyson Gay	USA	1sf2	Indianapolis, IN	22/06/2007	2007

Table 4.2: Number of data elements used for track events

	Year	Total	100m	200m	400m	800m	1000m	1500m	2000m	3000m	5000m	10000m
Senior Men	2007	1458	304	142	152	71	27	169	7	128	224	234
	2008	1789	410	260	257	201	15	194	3	132	253	64
	2009	1635	305	258	217	170	15	177	2	132	220	139
	2010	1568	226	222	212	196	25	194	4	106	216	167
	2011	1796	321	265	210	219	28	217	11	93	222	210
	8246		1566	1147	1048	857	110	951	27	591	1135	814
Senior Women	2007	1849	247	234	336	235	27	155	9	61	487	58
	2008	1949	270	280	358	283	15	164	4	102	260	213
	2009	1437	194	174	208	161	15	283	21	91	152	138
	2010	1524	183	178	235	167	25	273	9	106	193	155
	2011	1679	215	209	254	209	28	288	6	79	216	175
	8438		1109	1075	1391	1055	110	1163	49	439	1308	739
Junior Men (19)	2007	189	26	18	23	45	2	33		19	12	11
	2008	456	63	53	57	72	2	65		34	55	55
	2009	534	71	76	112	54	4	71		38	57	51
	2010	477	69	55	59	59	23	55		54	51	52
	2011	475	71	53	74	61	9	57		41	54	55
	2131		300	255	325	291	40	281		186	229	224
Junior Women (19)	2007	143	12	23	27	19	0	21		11	15	15
	2008	459	58	67	69	68	0	53		54	56	34
	2009	441	65	54	60	64	1	61		58	55	23
	2010	451	64	58	63	63	10	59		53	54	27
	2011	435	36	65	62	62	6	56		50	55	43
	1929		235	267	281	276	17	250		226	235	142
Youth Boys (17)	2007	179	36	35	26	27		28		27		
	2008	154	30	24	30	24		25		21		
	2009	228	42	36	40	36		39		35		
	2010	212	35	38	36	32		36		35		
	2011	243	35	39	44	44		40		41		
	1016		178	172	176	163		168		159		
Youth Girls (17)	2007	171	30	21	28	34		25		33		
	2008	143	18	24	25	27		26		23		
	2009	224	38	40	36	38		36		36		
	2010	216	36	33	37	37		35		38		
	2011	228	40	35	43	42		33		35		
	982		162	153	169	178		155		165		
Grand Totals	2007	3989	655	473	592	431	56	431	16	279	738	318
	2008	4950	849	708	796	675	32	527	7	366	624	366
	2009	4499	715	638	673	523	35	667	23	390	484	351
	2010	4448	613	584	642	554	83	652	13	392	514	401
	2011	4856	718	666	687	637	71	691	17	339	547	483
	22742		3550	3069	3390	2820	277	2968	76	1766	2907	1919

Table 4.3: Number of data elements used for Steeple Chace, Hurdles and Jump events

	Year	Total	2000m SC	3000m SC	100mH	110mH	400mH	High Jump	Pole Vault	Long Jump	Triple Jump
Senior Men	2007	1507		189		334	290	93	140	254	207
	2008	1533		195		248	256	205	134	283	212
	2009	1517		207		254	233	204	144	271	204
	2010	1365		198		246	193	176	140	226	186
	2011	1527		212		304	218	216	128	265	184
		7449		1001		1386	1190	894	686	1299	993
Senior Women	2007	1888		151	298		315	259	514	111	240
	2008	2186		331	364		278	280	439	232	262
	2009	1816		297	271		268	226	302	228	224
	2010	1626		256	256		243	215	225	212	219
	2011	1768		286	268		250	188	305	227	244
		9284		1321	1457		1354	1168	1785	1010	1189
Junior Men (19)	2007	146		19		17	19	20	30	23	18
	2008	446		62		59	63	67	70	59	66
	2009	450		56		63	63	66	71	60	71
	2010	441		56		62	62	74	65	61	61
	2011	418		64		60	51	67	66	51	59
		1901		257		261	258	294	302	254	275
Junior Women (19)	2007	157		22	32		20	20	23	17	23
	2008	434		54	63		55	76	64	61	61
	2009	483		59	74		63	71	76	67	73
	2010	441		67	55		63	87	54	59	56
	2011	421		62	58		63	65	60	56	57
		1936		264	282		264	319	277	260	270
Youth Boys (17)	2007	191	26			26	32	33	30	20	24
	2008	180	23			24	25	25	25	28	30
	2009	297	38			40	41	48	58	36	36
	2010	271	33			37	40	37	48	40	36
	2011	281	36			40	40	40	56	37	32
		1220	156			167	178	183	217	161	158
Youth Girls (17)	2007	226	23		29		33	30	42	27	42
	2008	194	24		25		26	38	27	26	28
	2009	285	39		47		39	43	40	37	40
	2010	282	33		47		33	43	48	39	39
	2011	278	42		44		37	38	40	36	41
		1265	161		192		168	192	197	165	190
Grand Totals	2007	4115	49	381	359	377	709	455	779	452	554
	2008	4973	47	642	452	331	703	691	759	689	659
	2009	4848	77	619	392	357	707	658	691	699	648
	2010	4426	66	577	358	345	634	632	580	637	597
	2011	4693	78	624	370	404	659	614	655	672	617
		23055	317	2843	1931	1814	3412	3050	3464	3149	3075

Table 4.4 – Number of data elements for Throw events, race walking and relays

	Year	Total	Shot Put	Discus Throw	Hammer Throw	Javelin Throw	5000mW	10000mW	20000mW	4x100m	4x200m	4x400m	4x800m
Senior Men	2007	1399	230	333	236	263			30	152	10	135	10
	2008	1579	380	377	252	253			14	161	13	129	0
	2009	1468	346	246	217	288			13	189	21	131	17
	2010	1414	371	250	167	299			9	156	16	119	27
	2011	1533	403	232	179	326			16	189	22	140	26
	7393		1730	1438	1051	1429			82	847	82	654	80
Senior Women	2007	1549	239	176	619	226			31	118	4	136	0
	2008	1790	305	180	725	229		22	5	160	6	158	0
	2009	1361	253	161	416	234		17	11	137	6	125	1
	2010	1324	239	187	385	241		17	0	115	6	132	2
	2011	1445	258	189	430	242		15	11	143	6	151	0
	7469		1294	893	2575	1172		71	58	673	28	702	3
Junior Men (19)	2007	122	17	23	14	33		12		11		12	
	2008	366	62	68	61	53		49		37		36	
	2009	403	64	70	85	67		50		35		32	
	2010	444	52	80	81	63		52		56		60	
	2011	415	62	70	60	69		52		51		51	
	1750		257	311	301	285		215		190		191	
Junior Women (19)	2007	155	34	21	42	23		10		14		11	
	2008	388	71	57	73	63		50		38		36	
	2009	439	65	77	81	59		50		52		55	
	2010	411	57	67	61	55		52		58		61	
	2011	403	57	66	57	67		50		55		51	
	1796		284	288	314	267		212		217		214	
Youth Boys (17)	2007	188	42	38	47	37		24					
	2008	140	28	27	41	22		22					
	2009	197	40	35	39	44		39					
	2010	204	51	38	38	41		36					
	2011	204	38	36	58	38		34					
	933		199	174	223	182		155					
Youth Girls (17)	2007	171	33	31	46	34	27						
	2008	163	36	39	30	33	25						
	2009	189	44	35	43	33	34						
	2010	201	44	44	43	39	31						
	2011	198	48	37	36	38	39						
	922		205	186	198	177	156						
Grand Totals	2007	3584	595	622	1004	616	27	46	61	295	14	294	10
	2008	4426	882	748	1182	653	25	143	19	396	19	359	0
	2009	4057	812	624	881	725	34	156	24	413	27	343	18
	2010	3998	814	666	775	738	31	157	9	385	22	372	29
	2011	4198	866	630	820	780	39	151	27	438	28	393	26
	20263		3969	3290	4662	3512	156	653	140	1927	110	1761	83

Additional data that must be considered are the current world records to verify that these will be reflected in the ranges of the models. The current world records used in this document was valid before the 2012 Olympic Games in London. These values are shown in Table 4.5 and Table 4.6. The data was updated on 20/07/2012

Table 4.5: World records for men as on 20/07/2012

World Records - Men						
Event	Perform	Wind	Athlete	Nat	Venue	Date
100m	9.58	0.9	Usain Bolt	JAM	Berlin	16/08/2009
200m	19.19	-0.3	Usain Bolt	JAM	Berlin	20/08/2009
400m	43.18		Michael	USA	Sevilla	26/08/1999
800m	1:41.01		David Lekuta	KEN	Rieti	29/08/2010
1000m	2:11.96		Noah Ngeny	KEN	Rieti	05/09/1999
1500m	3:26.00		Hicham El	MAR	Roma	14/07/1998
One Mile	3:43.13		Hicham El	MAR	Roma	07/07/1999
2000m	4:44.79		Hicham El	MAR	Berlin	07/09/1999
3000m	7:20.67		Daniel Komen	KEN	Rieti	01/09/1996
5000m	12:37.35		Kenenisa	ETH	Hengelo	31/05/2004
10000m	26:17.53		Kenenisa	ETH	Bruxelles	26/08/2005
20000m	56:26.0		Haile	ETH	Ostrava	27/06/2007
3000mSC	7:53.63		Saif Saaeed	QAT	Bruxelles	03/09/2004
110mH	12.87	0.9	Dayron Robles	CUB	Ostrava	12/06/2008
400mH	46.78		Kevin Young	USA	Barcelona	06/08/1992
HJ	2.45		Javier	CUB	Salamanca	27/07/1993
PV	6.14		Sergey Bubka	UKR	Sestriere	31/07/1994
LJ	8.95	0.3	Mike Powell	USA	Tokyo	30/08/1991
TJ	18.29	1.3	Jonathan	GBR	Göteborg	07/08/1995
SP	23.12		Randy Barnes	USA	Los Angeles, CA	20/05/1990
DT	74.08		Jürgen Schult	GDR	Neubrandenburg	06/06/1986
HT	86.74		Yuriy Sedykh	URS	Stuttgart	30/08/1986
JT	98.48		Jan Zeleznÿ	CZE	Jena	25/05/1996
Decathlon	9026		Roman Šebrle	CZE	Götzis	27/05/2001
20000mW	1:17:25.6		Bernardo	MEX	Bergen (Fana)	07/05/1994
4x100m	37.04		Jamaica	JAM	Daegu	04/09/2011
4x200m	1:18.68		Santa Monica	USA	Walnut, CA	17/04/1994
4x400m	2:54.29		United States	USA	Stuttgart	22/08/1993
4x800m	7:02.43		Kenya	KEN	Bruxelles	25/08/2006
4x1500m	14:36.23		Kenya	KEN	Bruxelles	04/09/2009

Table 4.6: World records for women as on 20/07/2012

World Records -Women						
Event	Perform	Wind	Athlete	Nat	Venue	Date
100m	10.49	0	Florence Griffith-	USA	Indianapolis, IN	16/07/1988
200m	21.34	1.3	Florence Griffith-	USA	Seoul	29/09/1988
400m	47.60		Marita Koch	GDR	Canberra	06/10/1985
800m	1:53.28		Jarmila Kratochvílová	TCH	München	26/07/1983
1000m	2:28.98		Svetlana Masterkova	RUS	Bruxelles	23/08/1996
1500m	3:50.46		Yunxia Qu	CHN	Beijing	11/09/1993
2000m	5:25.36		Sonia O'Sullivan	IRL	Edinburgh	08/07/1994
3000m	8:06.11		Junxia Wang	CHN	Beijing	13/09/1993
5000m	14:11.15		Tirunesh Dibaba	ETH	Oslo (Bislett)	06/06/2008
10000m	29:31.78		Junxia Wang	CHN	Beijing	08/09/1993
20000m	1:05:26.6		Tegla Loroupe	KEN	Borgholzhausen	03/09/2000
3000mSC	8:58.81		Gulnara Galkina	RUS	Beijing -	17/08/2008
100mH	12.21	0.7	Yordanka Donkova	BUL	Stara Zagora	20/08/1988
400mH	52.34		Yuliya Pechenkina	RUS	Tula	08/08/2003
HJ	2.09		Stefka Kostadinova	BUL	Roma	30/08/1987
PV	5.06		Elena Isinbaeva	RUS	Zürich	28/08/2009
LJ	7.52	1.4	Galina Chistyakova	URS	Leningrad	11/06/1988
TJ	15.50	0.9	Inessa Kravets	UKR	Göteborg	10/08/1995
SP	22.63		Natalya Lisovskaya	URS	Moskva	07/06/1987
DT	76.80		Gabriele Reinsch	GDR	Neubrandenburg	09/07/1988
HT	79.42		Betty Heidler	GER	Halle	21/05/2011
JT	72.28		Barbora Špotáková	CZE	Stuttgart	13/09/2008
Heptathlon	7291		Jackie Joyner-Kersee	USA	Seoul	24/09/1988
Decathlon	8358		Austra Skujyte	LTU	Columbia, MO	15/04/2005
10000mW	41:56.23		Nadezhda Ryashkina	URS	Seattle, WA	24/07/1990
20000mW	1:26:52.3		Olimpiada Ivanova	RUS	Brisbane	06/09/2001
4x100m	41.37		German Dem	GDR	Canberra	06/10/1985
4x200m	1:27.46		United States "Blue"	USA	Philadelphia, PA	29/04/2000
4x400m	3:15.17		USSR	URS	Seoul	01/10/1988
4x800m	7:50.17		USSR	URS	Moskva	05/08/1984

4.3 Data analysis

In a large number of events athletes compete in quarter finals, semi-finals and then progress to the final of the event. Top performers can then be listed 3 times in the top ranking list at the same meeting. These top athletes also participate at several meetings during the athletic season. The name of Usain Bolt from Jamaica, the current world record holder, appears 30 times in the 2007 to 2011 top performance lists. This will distort the data by including a large number of entries with achievements rarely obtained by other athletes. Based on the above, the author have decided to prevent this distortion by removing all repeating names in all events in a specific year. The remaining data is still sufficient to continue with the modelling. To illustrate the reduction effect, Table 4.7 contains the original and reduced number of records for the 100 meter men event.

Table 4.7: Reduced data by removing duplicate entries

100 meter Men			
Year	Original	Reduced	Removed
2007	304	190	114
2008	410	209	201
2009	305	193	112
2010	226	153	73
2011	321	189	132
Total	1566	934	632

The next phase is to determine the statistical parameters of the remaining data and to obtain the 5 year averages for selected positions. As a normal improvement in performance is expected, this will be verified for every 5th position in the ranking lists.

As performance averages increase continuously a weighted average will be used rather than a statistical average. The weighted average will be calculated using the formula:

$$Weighted\ average = \frac{\sum(Year\ performance)(Year\ weight)}{\sum(Year\ \ weights)}$$

Where the year weights used will be the values in Table 4.8. This distribution of weight will ensure that new data will have a greater influence than older data.

Table 4.8: Proposed multipliers for the 5 year weight values

2007	2008	2009	2010	2011
1	1	2	3	3

If the available data is insufficient, the total data for the 5 year period will be ordered and every 5th position of this list will be used to determine the formula parameters.

For events with less than 50 data points available the parameters will be extrapolated from similar events with sufficient available data.

4.4 Modelling possible cases

In industrial control systems various methods of control can be used. Each method has unique characteristics with specific advantages and disadvantages. Depending on the system to be controlled, different systems can be applied. The most common control systems used in industrial applications are proportional, derivative and integral control. A simple proportional control may be sufficient to stabilize the volume level of an amplifier but the more complex a system becomes the more investigation is required to determine the correct method of control. The most common method used in complex systems is the PID (Proportional + Integral + Derivative) method, combining all three of the basic methods.

As the human body is a complex system the method of measuring the performance in track and field athletics will have to reflect the behaviour of this complexity. However, this investigation will only consider the differences in performances achieved during actual meetings. Factors that actually determine the performances, such as training methods, diet, physical measurements of the athlete and psychological influences will be excluded.

The only environmental factors that will be considered after the final modellation will be the effect of height above sea level and the method of timing used.

In all models different cases will be considered with the aim to find a single formula with the minimum of constant values for all tables.

4.5.1 Linear model

Linear models are based on the mathematical relation $y = m.x + c$. The Purdy tables for track events are based on this model. As it does not reflect and reward the improvement of performance according to the effort required to improve correctly, this model will not be considered.

4.5.2 Exponential model

The mathematical formula is $y = a.e^{bx}$ where a and b are constants determining the shape of the graph. Figure 4.1 shows the effect of different values of the variable b.

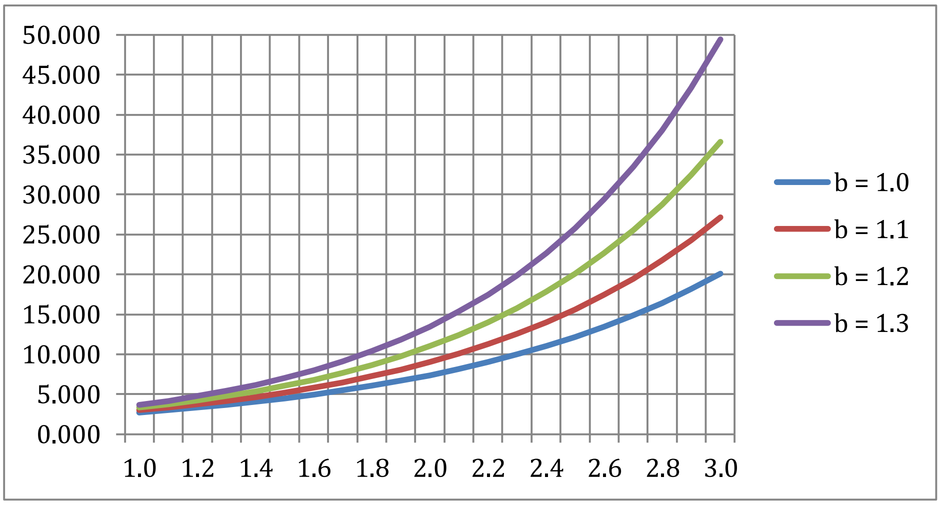

Figure 4.1: Exponential model with degrees of progression

Variations of *b* are shown in the graph. The values of *a* and *c* determine scaling and positioning. The Hungarian and the IAAF tables are based on a variation of this model where the base of natural logarithms, e, is replaced by a different base as in:

$y = a.(b - p)^2 + c$ (Hungarian) and $y = a.(b - p)^c$ (IAAF).

In their tables the values of *a*, *b* and *c* are determined from statistical values and they are different for each event.

4.5.3 Logarithmic model

This model is the inverse of the exponential model with the formula:

$y = a.log_b(x)$.

In the Hungarian and IAAF tables this is used to generate the printed versions of the tables using table scores to generate the corresponding performance values. It will thus be sufficient to consider the expanded exponential model.

This model can thus be used to determine the relation between athlete performances within a specific event. In the basic model the natural base *e* will be used giving the relation *y = a.ln(b.x)* as a base function.

4.5.4 Polynomial model

The general formula for this model is $y = \sum_{i=0}^{i=n} a_i x_i$ where *n* is a positive integer number. For any value of n greater than 1, the curve will have at least 1 turning point and the range of the variables must be selected such that even extreme expected performances will not pass the turning point resulting in lower scoring values.

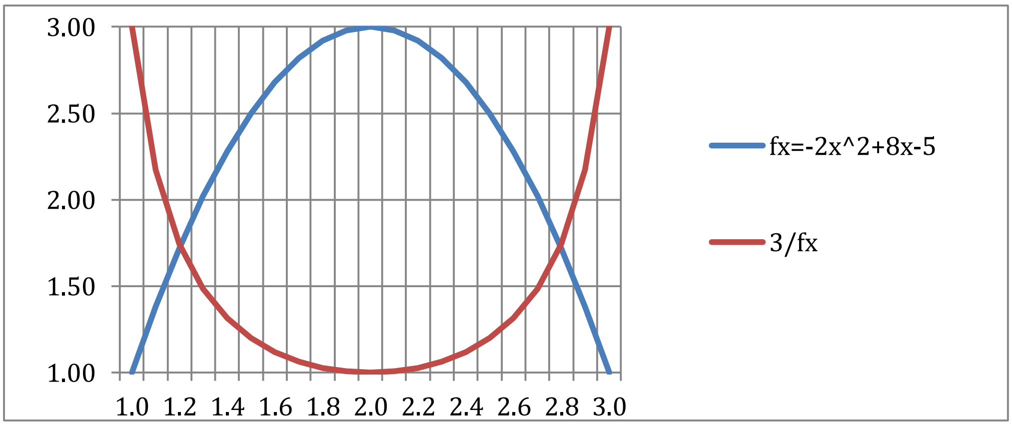

Figure 4.2: Typical 2nd order polynomial and an inverse of this graph.

Consider the simplistic 2nd order hyperbolic function $-2x^2 + 8x - 5$ and the inverse of this function scaled as $3/(-2x^2 + 8x - 5)$. For the range 1 to 3 these functions will have a turning point as 2. To have a useful range for this function the input data must be scaled to have a minimum value larger than 2 or the data must be scaled to provide a turning point at a negative performance value. For higher order functions both the minimum and maximum values will have to be scaled to select a useful section of the function.

4.5.5 Least mean squares model

The Least Mean Square (LMS) algorithm, introduced by Widrow and Hoff in 1959 is an adaptive algorithm, which uses a gradient-based method of steepest decent. The LMS algorithm uses the estimates of the gradient vector from the available data. LMS incorporates an iterative procedure that makes successive corrections to the result of the initial function in order to eventually find the minimum mean square error (Haykin & Widrow, 2003:12).

The initial application of this method is found in the optimization of control systems and it requires that an initial polynomial function must be selected and the LMS algorithm can then be applied to measured values to determine the polynomial coefficients that will produce the best fit curve of the polynomial to the measured data (Haykin & Widrow, 2003:18).

The number of iterations required to find the optimal values depends on the selection of the step size in the correction between iterations. A large value may overshoot the optimal value and a small value may require a large number of iterations before the optimal final value will be obtained. A method that was used with successful results is to start with a large value and then determine the point where the error changes sign. As soon a sign change is observed, use the previous point and reduce the step size by a factor 10. Repeat the process until the step size is equal to the desired accuracy.

This method in itself cannot be considered as a table formulation but it can be used to determine the constants required in any selected function. Purdy used this method to determine the constants for individual events in a first order polynomial or linear function ($y = a.x + b$). Each event will thus have its own set of values without considering the relation between different events.

4.5.6 Exponential functions

In this model the relation $y = a^{b.x}$ will be used with *a* as the natural base, *e*, as an initial value for the variable *a* in the formula. The function is progressive but tends to be aggressive (increasing too rapidly) as the values increase.

4.5.7 Hybrid model

Due to the complexity of the required formulation and considering the discussion above, it is obvious that a single solution may not apply but rather a combination of the above models. In the case studies individual models will be considered and then a combination of models to achieve an optimal formulation. A hybrid can also be constructed using the same function with different constants over sections of the function, interlinking at the change-over points.

4.6 Scaling parameters

The tables will be used by coaches, administrators of meetings, parents and athletes. The tables must thus be easy to read and to interpret. To facilitate this the resultant tables should have:

- A standard range from 0 to 1000 points. This will allow users to interpret results as percentages without complex calculations.

- All values calculated must be rounded down to integer values for readability and practical use.

- Current records should be represented by the 1000 point mark. This is only an approximate wish and will be regarded as a bonus if achieved.

- The 900 point value should represent athletes normally present in the final rounds of the South African national championship.

- The 700 point mark should represent athletes normally eligible for selection in a provincial team.

- The 500 point mark should represent athletes that can represent school teams at the provincial level.

The last 3 requirements may not be achievable in all events but it will used as guidelines in the determination of event constants and it can then be used as guidelines in the final tables to assist team managers in the selection of athletes for a specific meeting.

4.7 Model parameters

As the top performances in the world will be used to determine the model parameters, the 5th position will be used to set the 900 point mark on the table.

4.8 Reasons why technical standards are required

Technical standards ensure that the sport of athletics is accessible to men and women of all age categories. It regulates the imbalances that exist as a result of all athletes not being the same gender or age.

Technical standards are annually negotiated by administrators and implemented by the technical officials as the need is identified by the athletes and coaches. These standards contain a number of regulatory factors.

4.8.1 Age differences

The use of age group categories in athletics is one of the main reasons why the sport is so accessible. All ages from as early as 5 years old up to master athletes of 90 years and beyond can participate in athletics. As they only participate in their own age group and gender, all athletic participation is on equal ground.

In athletics all athletes in the same age group will compete against each other. This implies that athletes turning 15 in a specific year will be competing against all other athletes also turning 15 that year. Athletes older than 15 years of age will not be allowed to compete against a 15 year old athlete in the same race because they are physically stronger.

The opposite, however, is allowed. A 16 year old athlete may participate in a competition for 17 year old athletes. It is assumed that the 16 year old athlete is weaker than a 17 year old athlete and by competing against older athletes he or she will be at a disadvantage but may still exercise the choice to participate in the higher age group.

The range of age groups is broken down into groups identified as sub-youth (5 to 13 years old, normally in primary schools), youth (14 to 17 years old, normally in high schools), junior (18 and 19 years old, can be at high school, tertiary education or work), senior (20 to 29 years old) and masters (from 30 years old). This division of age groups is recognised by ASA and used by SASSA. The division from senior to masters is determined by the IAAF and a separate worldwide competition is available for master athletes.

4.8.2 Gender differences

Due to the difference between the physical strength and muscular abilities of men and women, separate races are organized for men and women.

4.8.3 Race distances

At younger ages the athlete's muscle composition and physical shape is not developed to run longer distances. Individual development, natural ability, personal preferences and training also influence the distance of races at different ages. To protect the athlete and to prevent exploitation by inexperienced coaches, the technical standards set limits for race distances for various age groups.

During the growing phase of the child, the body shape and strength is continuously changing. The cardiovascular system, hormonal systems and the energy systems are not as developed in a child as it is for an adult. To avoid growth disorders in the child, the distances of races are regulated.

4.8.4 Implement weight considerations

Due to the difference in physical strength between men, women and children, the weight of the implement in field events varies according to practical limitations. These variations are selected to optimize the performance of athletes without causing injury due to muscular stress. The physical size of implements also varies according to the age group.

4.8.5 Height limitations and distance between obstacles

In hurdle races the ideal is for the athlete to run over the hurdles rather than jumping over the hurdles and avoid getting injured in the process. The height of athletes varies according to age and hurdle heights are adjusted to reflect the average height of athletes in a specific age group.

To compensate for the difference in height of the athlete, not only the height of the hurdles but also the distance between the hurdles, the distance of the total hurdle race and the number of hurdles is regulated according the age of the athlete. This distance between hurdles is adjusted to accommodate the average running stride length of athletes.

4.8.6 Events per athlete limitation

To ensure maximum performance without injury or exhaustion, the number of events that an athlete may participate in during a one day meeting is set as 4 events of which only 1 can be longer than 200 meters or only 2 events if both are longer than 200 meters. At provincial and national levels the limitation is reduced to a maximum of 3 events. This reduction is used because at these levels athletes quite often participate in 1 or 2 qualifying rounds before the final event takes place.

4.8.7 Starting heights and increments for vertical jumps

To ensure that the total number of jumps for individual athletes are limited to prevent injury, the starting heights are normally set to accommodate not more than 15 jumps in total. That implies that the starting height will be approximately 7 times the increment value lower than the expected final height. The chief official at the event must be aware of the capabilities of the athletes at the meeting to set the starting heights and the increment values.

4.8.8 Consistency of events at different meetings

The primary function of a competition is to identify and rate athletes according to their performances. Athletes that perform well will get the opportunity to compete at a higher level of competition. The events listed in the competitions at lower levels will be determined by the list of events in the competition at higher levels. This arrangement is necessary to avoid subjectivity during the selection of teams for the next level of competition. It can’t be assumed that athletes running 300 meter races at a lower level will perform equally well in a 400 meter race. If the requirement at the higher level meeting is 400 meter, athletes should also run 400 meter at the lower level meetings. To save time in the meeting program some schools reduce the race walking event distances and then select athletes for the next level meeting based on the results of the shorter distances.

4.8.9 Order of events in combined events competitions

Combined events were the cornerstone of athletic competitions in ancient Greece. Combined events consist of 5, 7, 8 or 10 events depending on the age or gender of the athlete. To ensure consistency, the order in which the events take place are regulated and to comply with the exhaustion requirements, all combined competitions consisting of more than 5 events will be held over a two day period. The order will not include more than 1 event longer than 200 meters on any specific competition day.

4.9 Current technical standards

The standards for youth, junior and senior athletes are set by the IAAF and individual countries set the lower age standards to have a natural progression of standards between age groups and gender. To accommodate all the previous requirements, a panel of coaches and administrators determine the standards for distances, weights and hurdle heights for the different age groups. Changes in these standards are made if the transition to longer distances, increased weights or hurdle height is required to facilitate the development of the events. Any changes are published in circulars to schools, clubs and athletic administrators in advance for implementation in the next season. The current standards set by ASA for South Africa is shown in the following tables. The standards for senior athletes are excluded and can be found in the Handbook: Rules, 2012-2013. These standards apply to all nations and determine the events that will be available for athletics at the next Olympic Games.

Table 4.9: Technical standards for primary schools

Event	Boys/ Age								Girls/ Age							
	6	7	8	9	10	11	12	13	6	7	8	9	10	11	12	13
60m	x	x	x	x					x	x	x	x				
80m	x	x	x	x	x	x			x	x	x	x	x	x		
100m					x	x	x	x					x	x	x	x
150m							x								x	
200m								x								x
800m								x								x
1200m					x	x	x	x					x	x	x	x
70mH					x	x							x	x		
75mH							x								x	x
80mH								x								
150mH							x								x	
200mH								x								x
SP					x	x	x	x					x	x	x	x
DT							x	x							x	x
HJ					x	x	x	x					x	x	x	x
LJ					x	x	x	x					x	x	x	x
JT							x	x							x	x
1500mW								x								x

Table 4.10: Technical standards for secondary schools

Event	Boys/ Age				Girls/ Age			
	14	15	17	19	14	15	17	19
100m	x	x	x	x	x	x	x	x
200m	x	x	x	x	x	x	x	x
400m	x	x	x	x	x	x	x	x
800m	x	x	x	x	x	x	x	x
1500m	x	x	x	x	x	x	x	x
3000m		x	x	x			x	x
2000mSC			x					x
3000mSC				x				
80mH								
90mH					X	x		
100mH	x	x					x	x
110mH			x	x				
200mH								
300mH	X	x			x	x		
400mH			x	x			x	x
SP	x	x	x	x	x	x	x	x
DT	x	x	x	x	x	x	x	x
HJ	x	x	x	x	x	x	x	x
LJ	x	x	x	x	x	x	x	x
TJ	x	x	x	x	x	x	x	x
JT	x	x	x	x	x	x	x	x
HT		x	x	x		x	x	x
PV	x	x	x	x	x	x	x	x
3000mW		x	x	x		x	x	x

Table 4.11: Technical standards for events using implements

Event	Boys/Age				Girls/Age			
	10	**11**	**12**	**13**	**10**	**11**	**12**	**13**
SP	2 kg		3 kg	4 kg	2 kg		3 kg	
DT	x	x	750 g	1 kg	x	x	750 g	
JT	x	x	500 g	600 g	x	x	500 g	
	14	**15**	**17**	**19**	**14**	**15**	**17**	**19**
SP	4 kg		5 kg	6 kg	3 kg			4 kg
DT	1 kg		1,5 kg	1,75 kg	1 kg			
JT	600 g		700 g	800 g	500 g			600 g
HT	4 kg		5 kg	6 kg	3 kg			4 kg

Table 4.12: Technical standards for events using hurdles

Gender	Age	Distance In Meter	Height cm	Start to First Hurdle	Between Hurdles	Last Hurdle to Finish	Number of hurdles
Boys	**10**	70 m	68,0 cm	10,00 m	7,00 m	11,00 m	8
	11	70 m	68,0 cm	10,00 m	7,00 m	11,00 m	8
	12	75 m	76,2 cm	11,00 m	7,50 m	11,50 m	8
		150 m	68,0 cm	23,00 m	19,00 m	13,00 m	7
	13	80 m	76,2 cm	12,00 m	8,00 m	12,00 m	8
		200 m	68,0 cm	16,00 m	19,00 m	40,00 m	7
	14	100 m	84,0 cm	13,00 m	8,50 m	10,50 m	10
		200 m	84,0 cm	16,00 m	19,00 m	13,00 m	10
	15	100 m	84,0 cm	13,00 m	8,50 m	10,50 m	10
		300 m	84,0 cm	16,00 m	19,00 m	13,00 m	10
	17	110 m	91,4 cm	13,72 m	9,14 m	14,02 m	10
		400 m	84,0 cm	45,00 m	35,00 m	40,00 m	10
	19	110 m	99,5 cm	13,72 m	9,14 m	14,02 m	10
		400 m	91,4 cm	45,00 m	35,00 m	40,00 m	10
Girls	**10**	70 m	68,0 cm	10,00 m	7,00 m	11,00 m	8
	11	70 m	68,0 cm	10,00 m	7,00 m	11,00 m	8
	12	75 m	68,0 cm	11,00 m	7,50 m	11,50 m	8
		150 m	68,0 cm	23,00 m	19,00 m	13,00 m	7
	13	75 m	76,2 cm	11,00 m	7,50 m	11,50 m	8
		200 m	68,0 cm	16,00 m	19,00 m	13,00 m	10
	14	90 m	76,2 cm	13,00 m	8,00 m	13,00 m	9
		300 m	76,2 cm	50,00 m	35,00 m	40,00 m	7
	15	90 m	76,2 cm	13,00 m	8,00 m	13,00 m	9
		300 m	76,2 cm	50,00 m	35,00 m	40,00 m	7
	17	100 m	76,2 cm	13,00 m	8,50 m	10,50 m	10
		400 m	76,2 cm	45,00 m	35,00 m	40,00 m	10
	19	100 m	84,0 cm	13,00 m	8,50 m	10,50 m	10
		400 m	76,2 cm	45,00 m	35,00 m	40,00 m	10

4.10 Case development

In athletics there is a separation between track events and field events and within these there are additional areas of participation. The case studies will be developed considering all areas with the aim to find the common ground between the areas.

The different cases that will be considered are:

Track events with reference to sprints which predominantly require speed endurance. These are all events up to 400 meters, including the hurdle events.

Track events from 800 meters to 10 000 meters including distance walking and steeple chase events. As this investigation is focused on track and field athletics, road races will not be included. Road races range from 3 kilometres to ultra-marathons up to 100 kilometres. Additional factors such as road surfaces, inclines and descents and more, make it difficult to compare the results of different events over the same distance and it is therefore excluded.

Field events predominantly requiring power which includes all throwing events and pole vault.

The remaining field events, long jump and triple jump, are based on resilience factors and thus different from the other field events.

The next relation that will be considered is the effect of age difference in each of the previous cases.

Lastly the difference in gender will be considered, taking in account that the development is different between genders, depending on the age of the athlete.

4.11 Data to be used in the case evaluations.

In the evaluation of the different cases only reliable data will be used. These are the results from meetings where electronic timing was used, all officials were accredited and the meeting rules were according to those set by the IAAF.

The tables that will be developed must be applicable to South African standards and thus only meetings held under the jurisdiction of Athletics South Africa (ASA) will be used.

To set appropriate standards SA records will be considered in the determination of upper limits. These will however not be regarded as part of the data for formulation as records can be misleading.

The data over a 5 year period with weighted averages will be considered.

Results from international meetings will be used as verification of the derived formulations.

4.12 Summary

Considering the different available tables and different models used by these tables, it is evident that not one of the tables follows strict relations between events. Most tables apply a specific relation for the table set but no relation between events in the set. Each event is considered as an entity and constants are derived to represent that specific event. Each event type is considered separately and no coherence exists between events in any of the tables used for senior athletics on international level.

The remainder of this document will specifically be used to investigate these relations and then extend it to the relations between ages and genders.

Chapter 5: Case evaluations

5.1 Introduction

In preparation for the cases the data to be used will first be extracted from the raw material and then weighted for use. For this only South African data will be used and international data will act as confirmation data.

The shape of the raw data points selected can be used as a starting point for the different models. For each model the parameters will be determined and the confidence intervals on each parameter will be calculated to ultimately be able to determine the best formulation that can be applied to all events.

A program, Eureka.exe, will be used to calculate the equation parameters and determine the confidence value for the solutions.

The 5^{th} position will be used as the 900 point mark on the table.

5.2 Data selection

To ensure that the most reliable data is used only international data will be selected for the formulation. South African data will then be used to adjust the formula constants to South African standards.

Test data is selected from the reduced data. Starting with the 5^{th} position in the year ranking lists, every 5^{th} position is used up to the 50^{th} position. Events with insufficient data will be omitted and the final parameters for these events will be determined by extrapolation.

Using the above criteria the following tables represent the test data that will be used to evaluate the models for senior men.

Table 5.1: Senior Men 100 meter to 800 meter

Event	Position	2007	2008	2009	2010	2011	Weighted	Time/100m
100m	5	9.96	9.89	9.91	9.88	9.82	9.88	10.125
	10	10.02	9.95	9.94	9.95	9.89	9.94	10.063
	15	10.05	10	10	10	9.95	9.99	10.01
	20	10.07	10.02	10.02	10.03	9.99	10.02	9.981
	25	10.09	10.04	10.04	10.08	10.02	10.05	9.949
	30	10.11	10.06	10.05	10.1	10.06	10.08	9.926
	35	10.13	10.08	10.07	10.13	10.09	10.1	9.9
	40	10.14	10.1	10.09	10.14	10.11	10.12	9.884
	45	10.15	10.11	10.1	10.16	10.13	10.13	9.869
	50	10.15	10.13	10.11	10.17	10.14	10.14	9.859
200m	5	19.89	19.99	19.89	19.79	19.91	19.88	10.062
	10	20.06	20.17	20.17	20.11	20.16	20.14	9.931
	15	20.2	20.24	20.26	20.24	20.2	20.23	9.887
	20	20.3	20.29	20.3	20.36	20.29	20.31	9.845
	25	20.32	20.32	20.34	20.38	20.33	20.35	9.83
	30	20.33	20.37	20.37	20.42	20.39	20.39	9.81
	35	20.38	20.4	20.39	20.44	20.43	20.42	9.796
	40	20.43	20.43	20.41	20.48	20.46	20.45	9.78
	45	20.47	20.45	20.45	20.49	20.5	20.48	9.766
	50	20.49	20.47	20.46	20.53	20.51	20.5	9.756
400m	5	44.46	44.6	44.74	44.7	44.68	44.67	8.955
	10	44.62	44.7	44.81	44.81	44.78	44.77	8.934
	15	44.92	44.8	44.98	44.87	44.86	44.89	8.911
	20	45.05	44.9	45.14	45.01	45.01	45.03	8.883
	25	45.22	45.02	45.21	45.1	45.19	45.15	8.859
	30	45.25	45.12	45.28	45.15	45.27	45.22	8.846
	35	45.29	45.19	45.35	45.24	45.3	45.28	8.834
	40	45.35	45.24	45.54	45.32	45.42	45.39	8.813
	45	45.4	45.31	45.55	45.44	45.46	45.45	8.801
	50	45.44	45.47	45.57	45.5	45.51	45.51	8.79
800m	5	103.94	103.26	103.17	103.45	103.37	103.4	7.737
	10	104.27	104.1	103.82	103.89	104.07	103.99	7.693
	15	104.54	104.63	104.47	104.56	104.31	104.47	7.658
	20	104.78	104.75	104.86	104.77	104.64	104.75	7.637
	25	105.13	105.02	105.36	105.23	104.83	105.11	7.611
	30	105.47	105.29	105.48	105.54	105.06	105.35	7.594
	35	105.61	105.47	105.64	105.74	105.14	105.5	7.583
	40	105.84	105.58	105.9	105.85	105.36	105.69	7.57
	45	105.9	105.65	106.07	105.92	105.47	105.79	7.562
	50	106.07	105.79	106.16	106.06	105.52	105.89	7.555

Table 5.2: Senior Men 1500 meter to 10000 meter

Event	Pos	2007	2008	2009	2010	2011	Weighted	Time/100m
1500m	5	211.49	211.94	211.21	211.06	211.37	211.31	7.098
	10	212.13	212.16	211.9	212.2	211.84	212.02	7.075
	15	213.04	213.06	212.6	212.82	212.45	212.71	7.052
	20	214.09	213.63	213.63	213.67	213.42	213.63	7.022
	25	214.52	214.06	213.98	214.17	213.66	214.00	7.009
	30	215.03	214.67	214.34	214.5	214.13	214.43	6.995
	35	215.32	215.05	214.6	214.98	214.43	214.78	6.984
	40	216.04	215.53	215.07	215.17	214.59	215.10	6.974
	45	216.22	215.73	215.47	215.74	214.72	215.43	6.963
	50	216.49	216.00	215.96	215.98	215.52	215.89	6.948
3000m	5	453.06	453.01	451.20	451.41	450.15	451.32	6.647
	10	454.94	456.08	452.46	454.32	453.5	453.94	6.609
	15	456.34	457.66	453.15	457.33	455.66	455.93	6.58
	20	457.77	459.45	457.05	459.01	460.10	458.87	6.538
	25	458.77	460.79	457.84	460.26	460.93	459.88	6.523
	30	460.88	461.61	461.14	461.38	462.11	461.52	6.5
	35	462.32	463.09	461.95	462.67	464.12	462.97	6.48
	40	462.94	463.97	463.26	463.34	466.29	464.23	6.462
	45	463.82	465.85	464.49	464.98	469.11	466.09	6.436
	50	465.43	467.27	465.51	466.38	469.63	467.18	6.422
5000m	5	771.00	777.56	776.27	774.59	779.20	776.25	6.441
	10	782.89	783.04	778.16	779.01	780.20	779.99	6.41
	15	786.51	785.27	779.27	780.15	784.60	782.46	6.39
	20	787.10	786.52	783.06	784.65	788.00	785.77	6.363
	25	787.89	787.88	785.02	788.43	790.20	788.17	6.344
	30	790.68	788.64	787.47	790.55	791.50	790.04	6.329
	35	792.18	790.19	789.34	791.75	792.20	791.29	6.319
	40	793.08	791.69	791.01	793.03	793.70	792.70	6.308
	45	794.85	792.4	791.64	795.19	795.20	794.17	6.296
	50	795.91	793.51	793.2	795.53	795.90	795.01	6.289
10000m	5	1609.55	1617.08	1619.88	1630.74	1608.35	1618.37	6.179
	10	1620.30	1628.06	1635.94	1637.61	1612.84	1627.16	6.146
	15	1624.92	1633.85	1645.24	1647.79	1615.73	1633.98	6.120
	20	1632.42	1636.99	1650.08	1649.82	1633.67	1642.00	6.090
	25	1646.31	1639.81	1658.25	1653.09	1643.82	1649.34	6.063
	30	1650.50	1647.64	1661.99	1660.07	1645.63	1653.92	6.046
	35	1653.48	1651.61	1667.81	1670.40	1649.40	1660.01	6.024
	40	1658.56	1654.29	1669.52	1673.13	1651.46	1662.57	6.015
	45	1663.13	1656.36	1672.1	1675.02	1657.21	1666.04	6.002
	50	1665.59	-	1677.61	1677.53	1661.32	1670.82	5.985

Table 5.3: Senior Men Hurdles, Steeple Chase and Relays

Event	Pos	2007	2008	2009	2010	2011	Weighted	Time/100m
110mH	5	13.02	13.15	13.13	13.19	13.12	13.14	8.374
	10	13.19	13.24	13.21	13.28	13.23	13.24	8.309
	15	13.27	13.30	13.29	13.34	13.29	13.30	8.268
	20	13.33	13.35	13.34	13.38	13.35	13.36	8.237
	25	13.36	13.37	13.36	13.44	13.37	13.39	8.216
	30	13.40	13.41	13.39	13.47	13.41	13.42	8.195
	35	13.47	13.44	13.42	13.50	13.44	13.46	8.174
	40	13.51	13.46	13.44	13.52	13.46	13.48	8.161
	45	13.54	13.49	13.49	13.54	13.48	13.51	8.144
	50	13.56	13.53	13.51	13.55	13.49	13.52	8.134
400mH	5	48.12	48.30	48.09	47.86	47.99	48.02	8.331
	10	48.26	48.52	48.30	48.47	48.47	48.42	8.261
	15	48.51	48.71	48.67	48.68	48.72	48.68	8.218
	20	48.88	48.93	49.04	49.01	49.04	49.0	8.163
	25	49.04	49.15	49.31	49.19	49.17	49.19	8.132
	30	49.13	49.22	49.41	49.35	49.28	49.31	8.113
	35	49.24	49.39	49.54	49.45	49.43	49.44	8.091
	40	49.30	49.48	49.66	49.58	49.59	49.56	8.071
	45	49.47	49.56	49.68	49.68	49.66	49.64	8.058
	50	49.56	49.70	49.78	49.77	49.76	49.74	8.042
3000mSC	5	486.66	489.05	483.17	483.72	485.72	485.04	6.185
	10	489.72	492.72	490.63	489.87	488.43	489.86	6.124
	15	494.32	494.32	492.13	496.46	491.81	493.77	6.076
	20	495.66	495.80	494.51	497.92	494.22	495.69	6.052
	25	497.03	497.37	497.94	499.50	496.41	497.80	6.027
	30	498.43	500.07	500.58	501.15	497.84	499.66	6.004
	35	500.43	501.16	502.50	502.34	499.33	501.16	5.986
	40	501.36	501.99	504.22	503.23	501.77	502.68	5.968
	45	502.91	502.20	505.79	504.05	502.61	503.67	5.956
	50	503.40	503.28	506.50	505.39	503.36	504.59	5.945
4x100m	5	38.03	38.15	37.92	38.17	38.18	38.11	10.497
	10	38.56	38.48	38.40	38.44	38.41	38.44	10.406
	15	38.81	38.75	38.57	38.69	38.65	38.67	10.343
	20	38.95	38.87	38.72	38.83	38.72	38.79	10.312
	25	39.05	38.94	38.93	38.96	38.92	38.95	10.270
	30	39.18	39.16	39.06	39.12	39.04	39.09	10.232
	35	39.30	39.22	39.22	39.20	39.09	39.18	10.209
	40	39.35	39.28	39.29	39.28	39.23	39.27	10.185
	45	39.46	39.37	39.33	39.36	39.29	39.34	10.167
	50	39.48	39.46	39.38	39.43	39.34	39.40	10.152
4x400m	5	180.04	179.37	180.53	180.60	180.22	180.29	8.874
	10	181.22	180.32	181.65	181.72	180.68	181.20	8.830
	15	182.48	182.00	182.23	182.6	181.33	182.07	8.788
	20	183.49	182.94	182.45	182.91	181.84	182.56	8.764
	25	183.99	184.09	183.25	183.45	183.33	183.49	8.720
	30	184.74	184.33	183.81	183.78	184.05	184.02	8.695
	35	185.14	184.64	184.27	184.10	184.38	184.38	8.678
	40	185.70	184.85	185.35	184.30	184.77	184.85	8.656
	45	186.00	185.16	185.63	184.86	185.64	185.39	8.630
	50	186.17	185.32	185.98	185.46	185.72	185.70	8.616

Table 5.4: Senior Men Field Jump events

Event	Pos	2007	2008	2009	2010	2011	Weighted
HJ	5	2.34	2.34	2.33	2.33	2.35	2.34
	10	2.32	2.32	2.32	2.30	2.32	2.31
	15	2.30	2.30	2.31	2.30	2.31	2.31
	20	2.30	2.30	2.31	2.28	2.31	2.30
	25	2.30	2.30	2.28	2.28	2.30	2.29
	30	2.30	2.30	2.28	2.28	2.28	2.28
	35	2.29	2.27	2.28	2.26	2.28	2.27
	40	2.27	2.27	2.28	2.26	2.28	2.27
	45	2.27	2.27	2.26	2.26	2.27	2.27
	50	2.27	2.27	2.26	2.25	2.26	2.26
PV	5	5.87	5.82	5.80	5.80	5.85	5.82
	10	5.82	5.8	5.75	5.75	5.75	5.76
	15	5.81	5.75	5.72	5.73	5.72	5.74
	20	5.75	5.71	5.70	5.70	5.72	5.71
	25	5.71	5.70	5.70	5.65	5.65	5.67
	30	5.70	5.70	5.70	5.61	5.62	5.65
	35	5.70	5.70	5.65	5.60	5.62	5.64
	40	5.66	5.65	5.65	5.60	5.60	5.62
	45	5.61	5.61	5.61	5.55	5.60	5.59
	50	5.60	5.60	5.60	5.5	5.55	5.56
LJ	5	8.34	8.36	8.43	8.33	8.37	8.37
	10	8.26	8.25	8.3	8.24	8.27	8.26
	15	8.22	8.22	8.23	8.22	8.26	8.23
	20	8.19	8.21	8.20	8.19	8.21	8.2
	25	8.17	8.16	8.18	8.15	8.18	8.17
	30	8.12	8.15	8.15	8.12	8.15	8.14
	35	8.10	8.11	8.11	8.11	8.12	8.11
	40	8.08	8.10	8.11	8.09	8.10	8.10
	45	8.04	8.08	8.09	8.06	8.08	8.07
	50	8.02	8.05	8.05	8.06	8.05	8.05
TJ	5	17.52	17.50	17.62	17.49	17.68	17.58
	10	17.35	17.43	17.32	17.22	17.29	17.30
	15	17.27	17.3	17.20	17.14	17.21	17.20
	20	17.13	17.2	17.16	17.07	17.08	17.11
	25	17.10	17.12	17.10	17.01	17.02	17.05
	30	17.01	17.07	17.06	16.93	16.97	16.99
	35	16.96	17.03	17.00	16.90	16.90	16.94
	40	16.90	17.00	16.97	16.86	16.86	16.90
	45	16.87	16.95	16.91	16.82	16.82	16.86
	50	16.81	16.85	16.83	16.76	16.79	16.80

Table 5.5: Senior Men Field Throw events

Event	Pos	2007	2008	2009	2010	2011	Weighted
SP	5	21.27	21.51	21.37	21.97	22.07	21.76
	10	20.81	21.03	20.99	21.25	21.00	21.06
	15	20.67	20.88	20.64	20.69	20.82	20.74
	20	20.53	20.78	20.50	20.55	20.72	20.61
	25	20.35	20.60	20.43	20.38	20.58	20.47
	30	20.20	20.53	20.39	20.20	20.38	20.33
	35	20.07	20.38	20.28	20.06	20.20	20.18
	40	20.01	20.27	20.20	20.00	20.13	20.11
	45	19.94	20.20	20.09	19.95	20.06	20.04
	50	19.88	20.12	20.00	19.80	19.88	19.90
DT	5	68.26	68.90	68.49	69.69	67.99	68.72
	10	66.61	67.91	66.19	66.90	67.21	66.92
	15	65.77	65.84	65.56	66.20	66.87	66.19
	20	64.96	65.31	64.90	65.33	66.04	65.42
	25	64.52	64.79	64.47	64.74	65.74	64.97
	30	64.14	64.63	63.67	64.28	65.03	64.40
	35	63.37	64.26	63.11	63.70	64.47	63.84
	40	62.99	63.59	62.85	63.32	64.30	63.51
	45	62.76	63.09	62.64	62.88	63.89	63.14
	50	62.36	62.87	62.30	62.69	63.35	62.80
HT	5	81.60	81.70	80.10	79.64	80.31	80.34
	10	80.00	80.45	79.48	78.73	79.27	79.34
	15	78.60	79.97	78.87	78.13	78.54	78.63
	20	77.92	79.46	77.78	77.35	77.52	77.76
	25	77.38	78.79	76.81	77.01	76.60	77.06
	30	76.95	78.54	76.38	76.55	76.40	76.71
	35	76.32	77.32	75.44	76.07	76.09	76.10
	40	75.93	76.97	74.95	75.42	75.75	75.63
	45	75.20	76.28	74.76	74.83	75.31	75.14
	50	74.95	75.76	74.23	74.20	74.76	74.61
JT	5	87.46	86.88	86.41	86.53	87.12	86.81
	10	84.35	85.05	84.24	85.12	84.81	84.77
	15	83.38	83.50	83.24	83.81	84.38	83.79
	20	82.71	83.20	82.65	83.17	83.77	83.20
	25	82.23	82.06	82.06	82.33	82.61	82.32
	30	80.73	81.42	81.64	81.12	82.29	81.57
	35	80.34	80.72	81.21	80.38	81.62	80.95
	40	79.85	80.40	81.05	79.91	81.01	80.51
	45	79.45	79.77	80.22	79.65	80.45	80.00
	50	78.97	79.38	80.01	79.35	80.33	79.74

Table 5.6: Senior Men summarised test data

Position	100m	200m	400m	800m	1500m	3000m	5000m	10000m
5	10.13	10.06	8.96	7.74	7.10	6.65	6.44	6.18
10	10.06	9.93	8.93	7.69	7.08	6.61	6.41	6.15
15	10.01	9.89	8.91	7.66	7.05	6.58	6.39	6.12
20	9.98	9.85	8.88	7.64	7.02	6.54	6.36	6.09
25	9.95	9.83	8.86	7.61	7.01	6.52	6.34	6.06
30	9.93	9.81	8.85	7.59	7.00	6.50	6.33	6.05
35	9.90	9.80	8.83	7.58	6.98	6.48	6.32	6.02
40	9.88	9.78	8.81	7.57	6.97	6.46	6.31	6.02
45	9.87	9.77	8.80	7.56	6.96	6.44	6.30	6.00
50	9.86	9.76	8.79	7.56	6.95	6.42	6.29	5.99

Position	110mH	400mH	3000mSC	4x100m	4x400m	HJ	PV	LJ
5	8.37	8.33	6.19	10.50	8.87	2.34	5.82	8.37
10	8.31	8.26	6.12	10.41	8.83	2.31	5.76	8.26
15	8.27	8.22	6.08	10.34	8.79	2.31	5.74	8.23
20	8.24	8.16	6.05	10.31	8.76	2.30	5.71	8.20
25	8.22	8.13	6.03	10.27	8.72	2.29	5.67	8.17
30	8.20	8.11	6.00	10.23	8.70	2.28	5.65	8.14
35	8.17	8.09	5.99	10.21	8.68	2.27	5.64	8.11
40	8.16	8.07	5.97	10.19	8.66	2.27	5.62	8.10
45	8.14	8.06	5.96	10.17	8.63	2.27	5.59	8.07
50	8.13	8.04	5.95	10.15	8.62	2.26	5.56	8.05

Position	TJ	SP	DT	HT	JT
5	17.58	21.76	68.72	80.34	86.81
10	17.30	21.06	66.92	79.34	84.77
15	17.20	20.74	66.19	78.63	83.79
20	17.11	20.61	65.42	77.76	83.20
25	17.05	20.47	64.97	77.06	82.32
30	16.99	20.33	64.40	76.71	81.57
35	16.94	20.18	63.84	76.10	80.95
40	16.90	20.11	63.51	75.63	80.51
45	16.86	20.04	63.14	75.14	80.00
50	16.80	19.90	62.80	74.61	79.74

5.3 Model evaluations for the Senior Men case

To select the best type of fit it is required to start with the most simplistic formulae for each method and then determine the parameters and confidence of the best fit for each method.

The following will be considered:

Logarithmic function: $y = a.ln(x) + c$

n^{th} Order polynomial function:

$y = \sum a_n.x^n$ with n a series of positive integer numbers.

In the simplistic case the 2nd order polynomial $a.x^2 + b.x + c$ will be used.

Exponential function: $y = a.x^b$ and $y = a.e^{b.x}$

Where: x is the performance for position y. The values of a, b and c are constants for each event.

For the determination of these constants and in the following graphical comparisons, the data was used up to the 100th position in steps of 5, giving 20 data points per event.

5.3.1 Model comparisons

In all of the following figures, showing the results that were obtained, the blue lines indicate the actual data and the red lines are the closest fit functions.

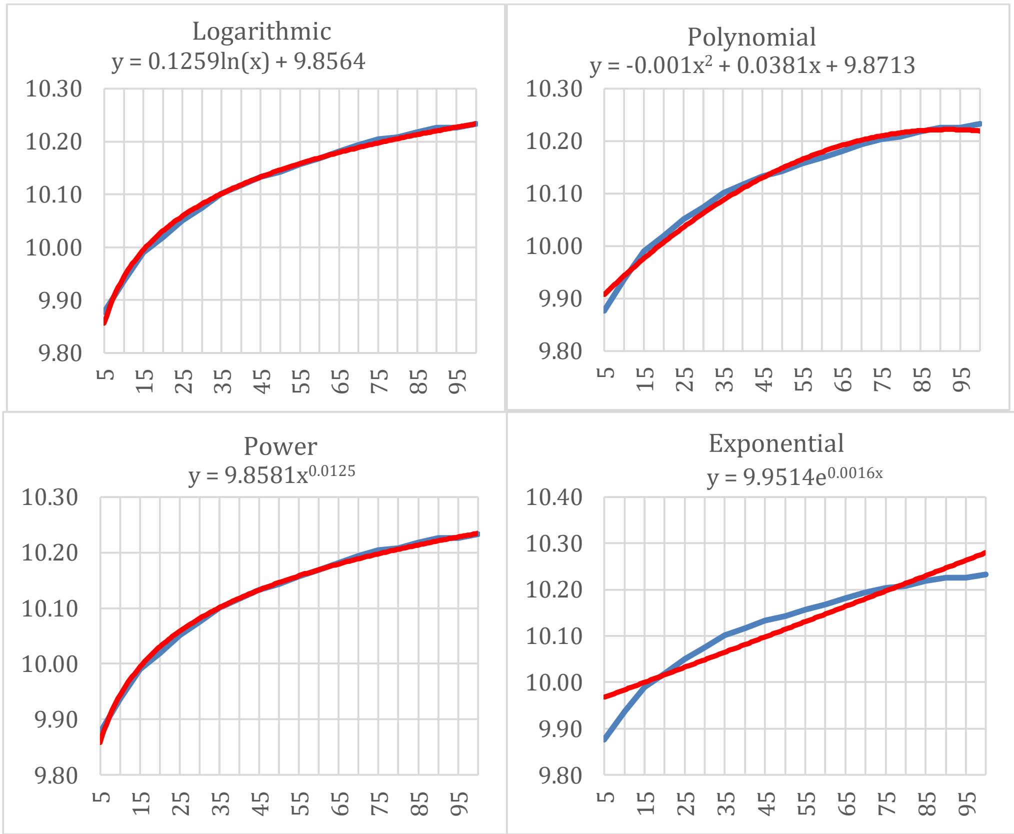

Figure 5.1 100 meter Senior Men

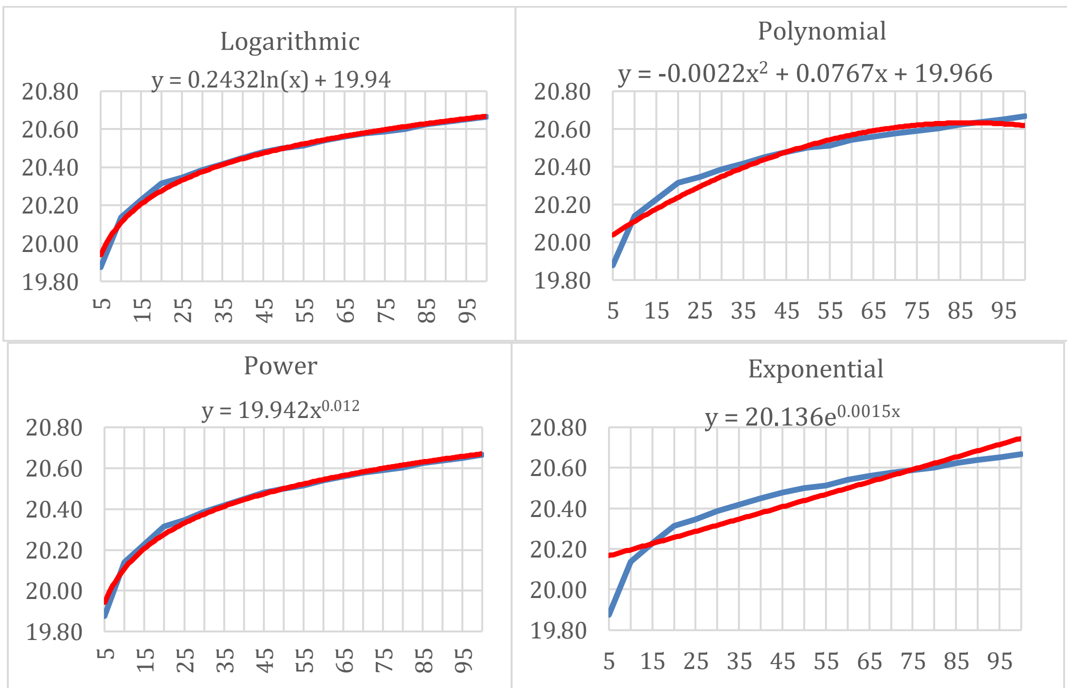

Figure 5.2 - 200 meter Senior Men

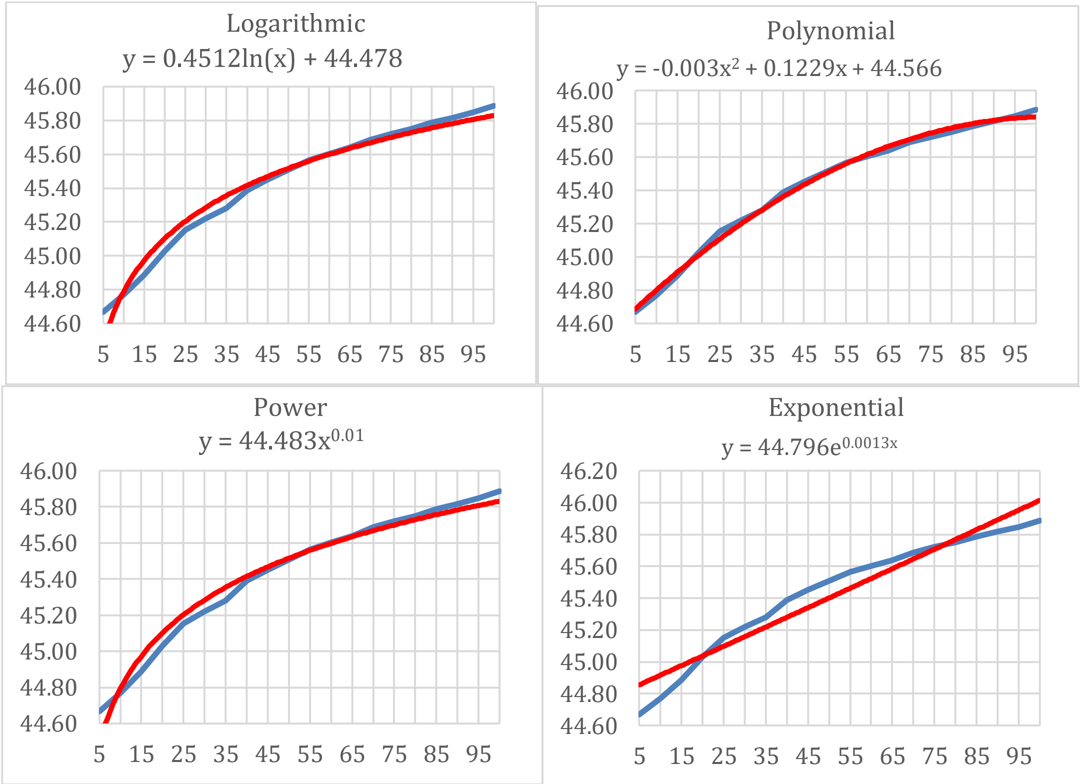

Figure 5.3: 400 meter Senior Men

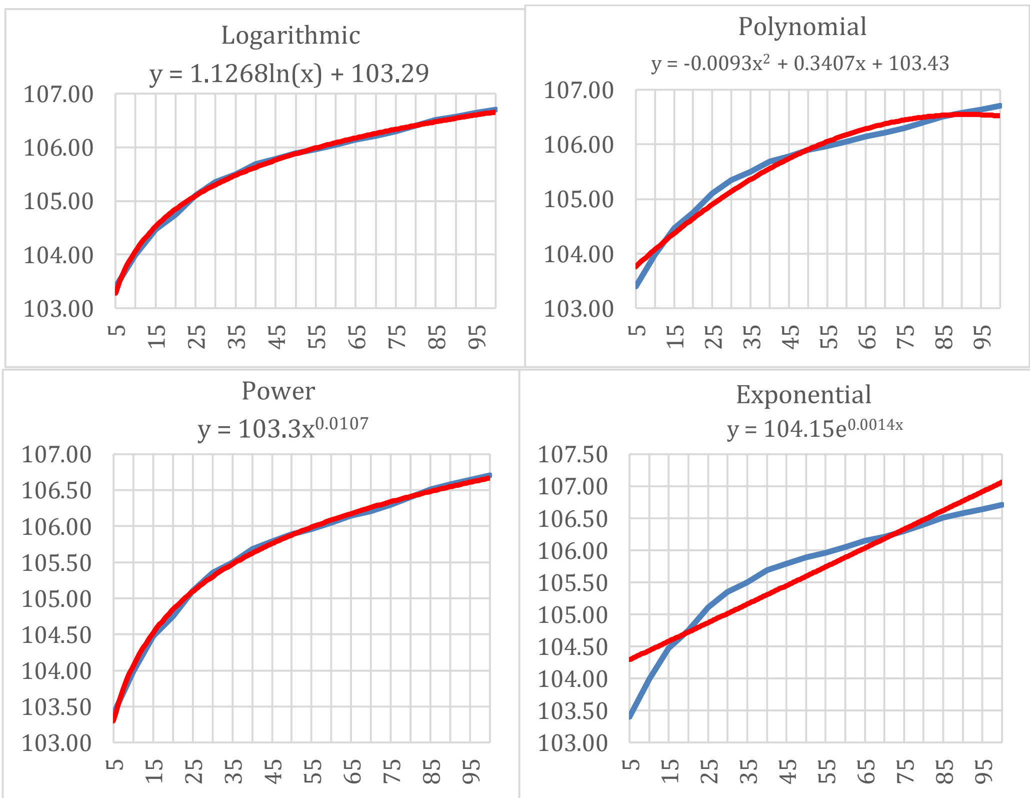

Figure 5.4: 800 meter Senior Men

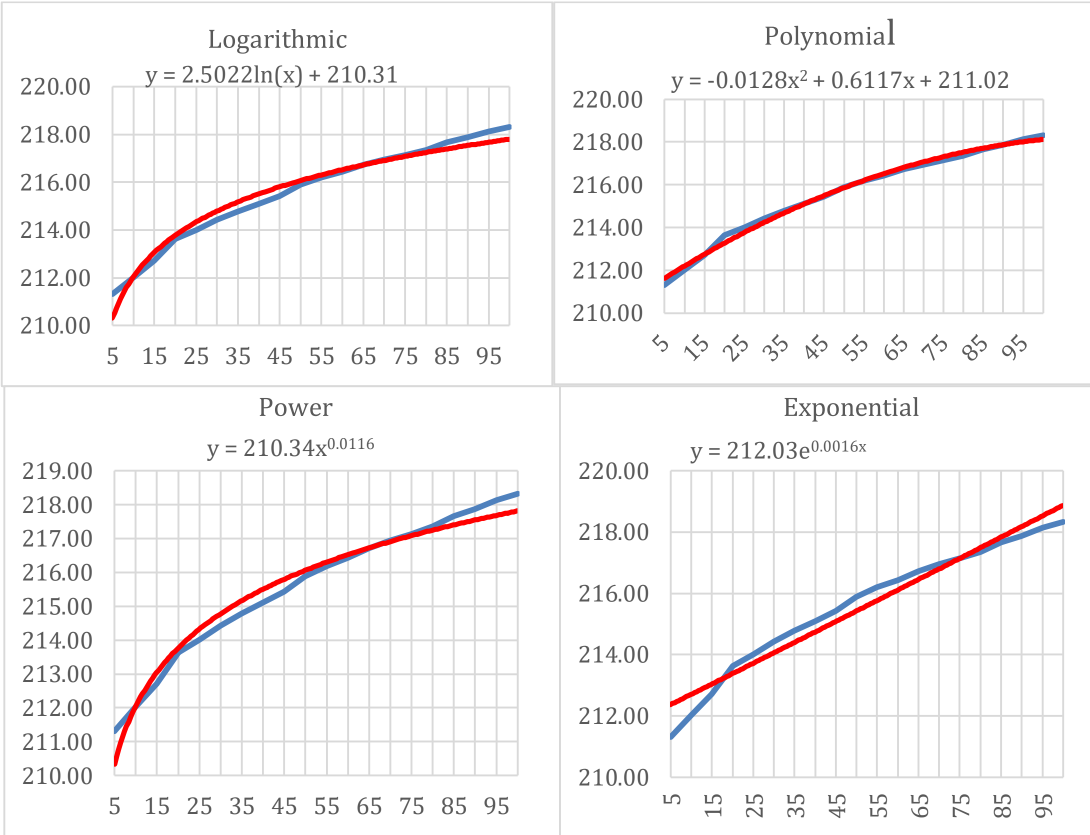

Figure 5.5: 1500 meter Senior Men

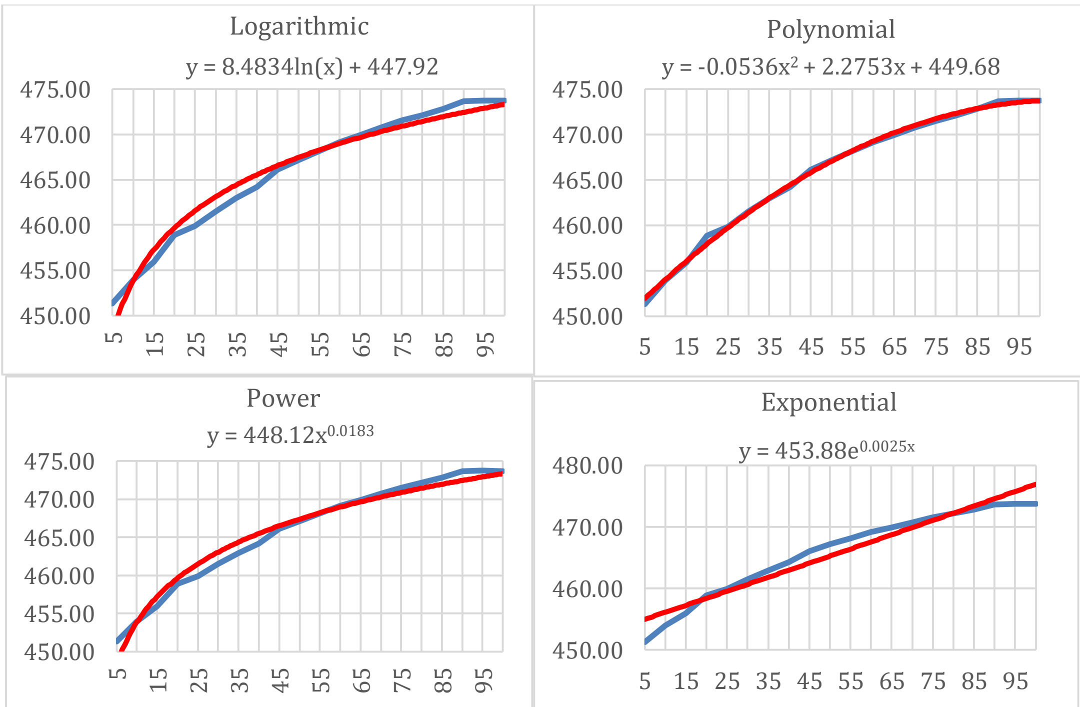

Figure 5.6: 3000 meter Senior Men

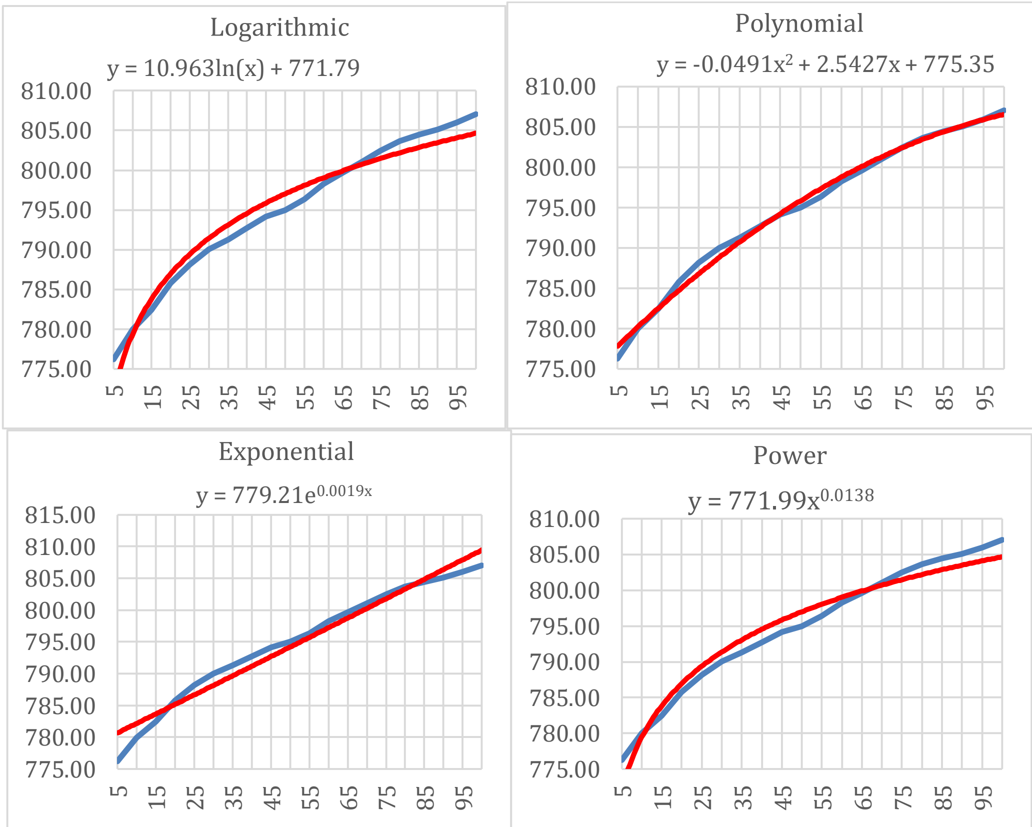

Figure 5.7: 5000 meter Senior Men

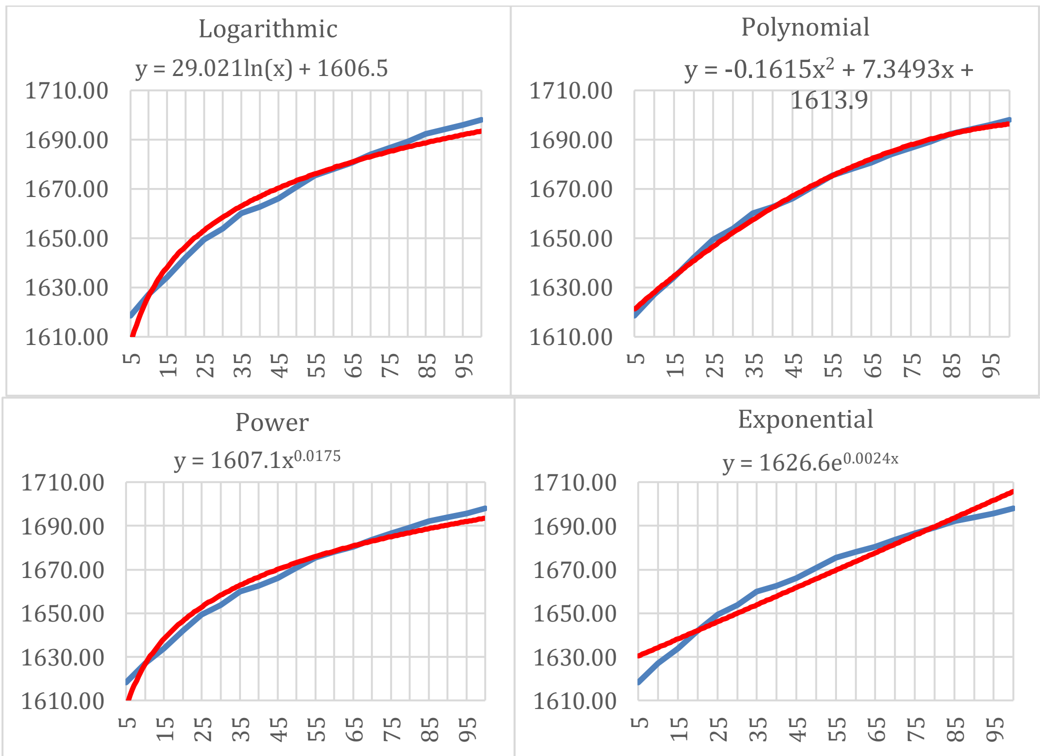

Figure 5.8: 10000 meter Senior Men

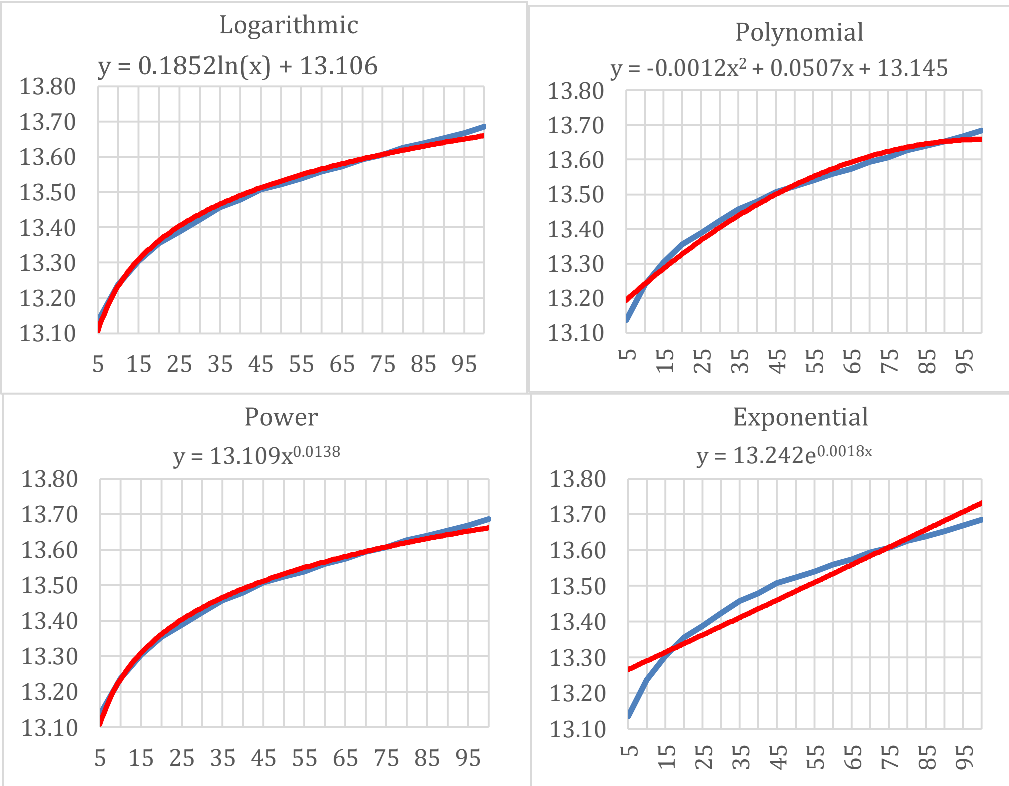

Figure 5.9: 110 meter Hurdles Senior Men

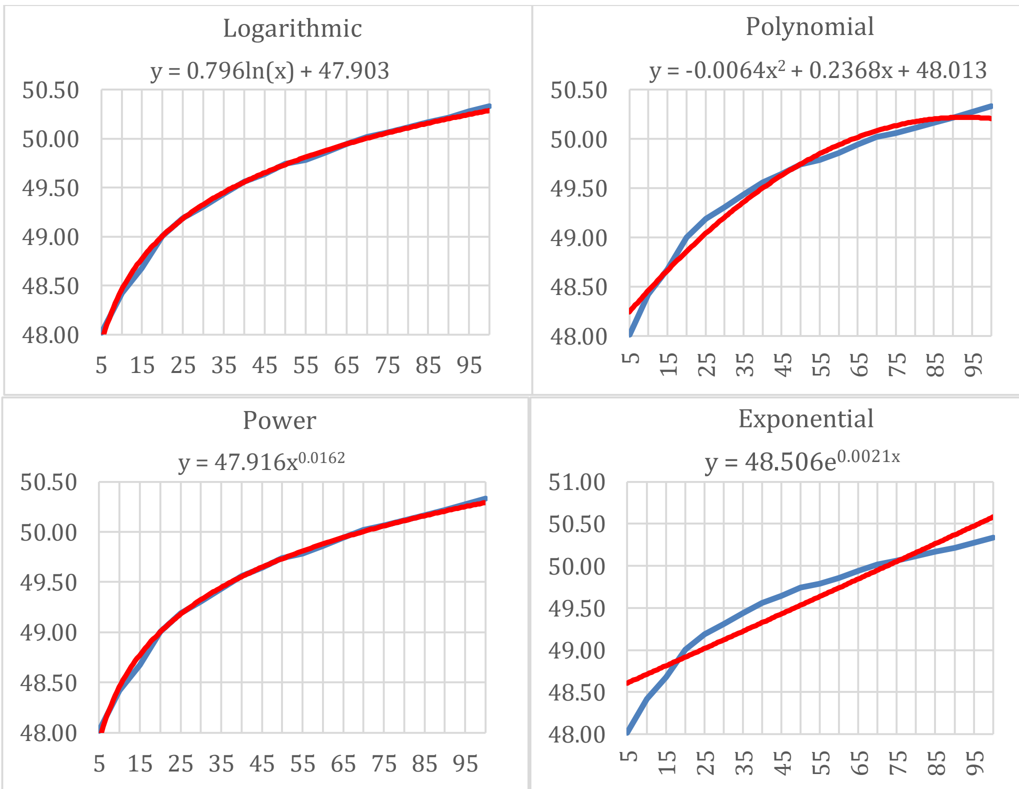

Figure 5.10: 400 meter Hurdles Senior Men

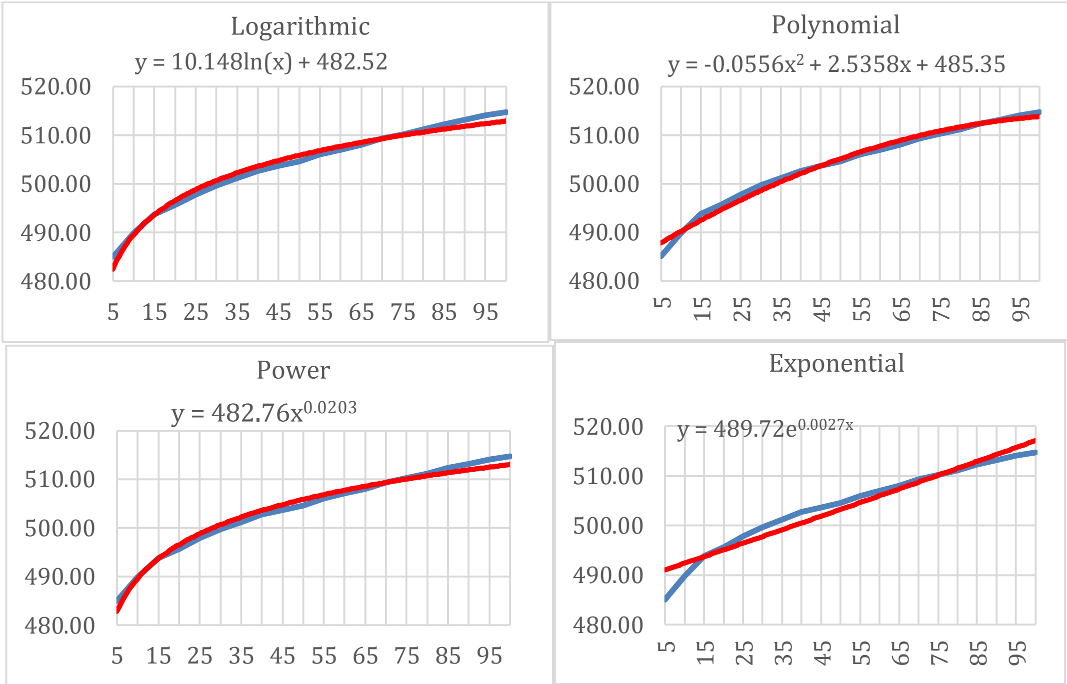

Figure 5.11: 3000 meter Steeple Chase Senior Men

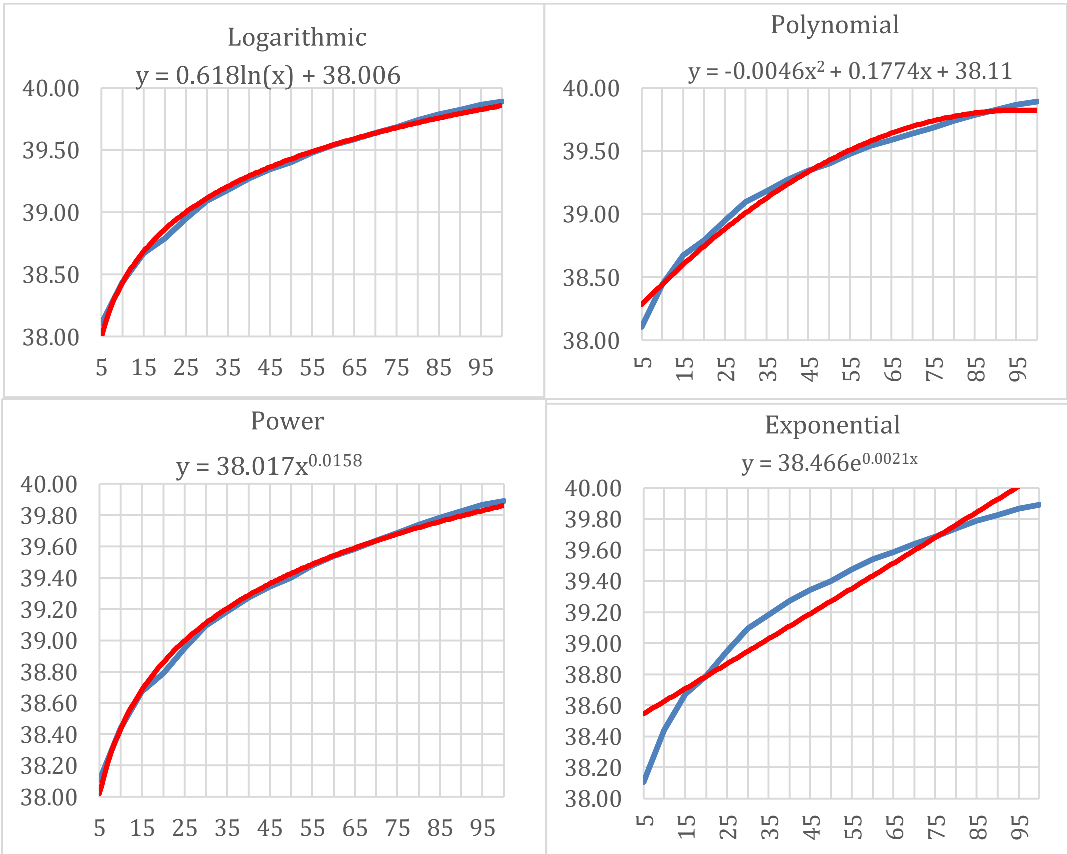

Figure 5.12: 4 x 100 meter Relay Senior Men

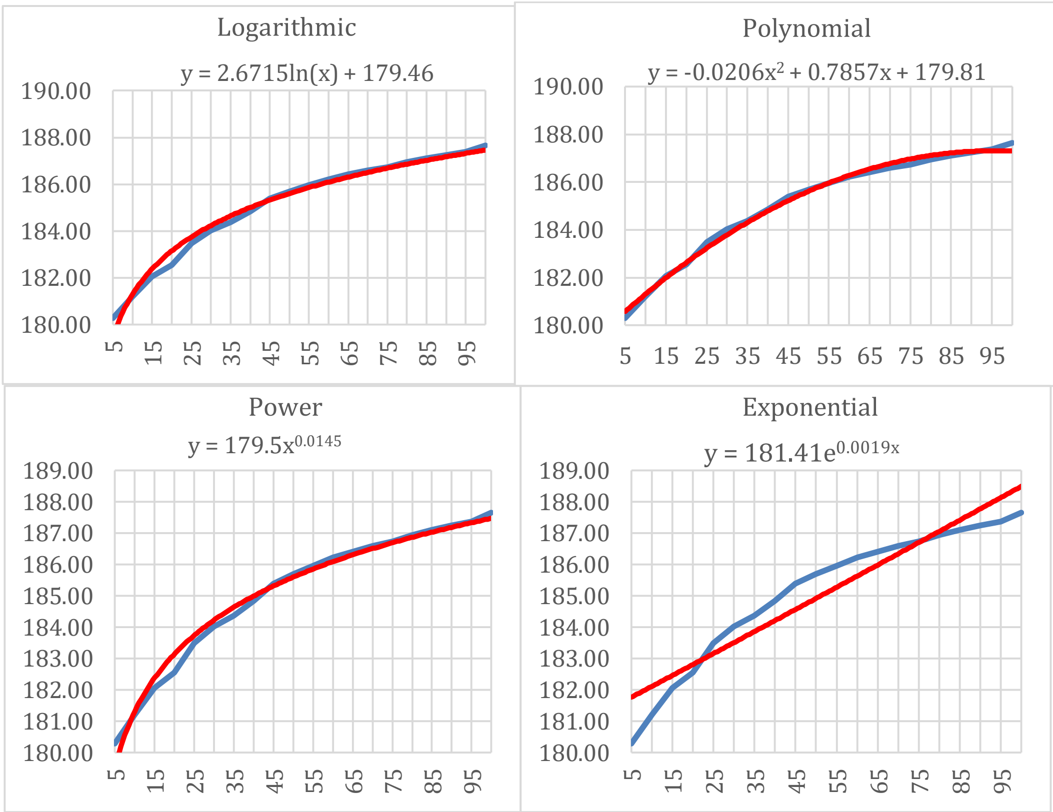

Figure 5.13: 4 x 400 meter Relay Senior Men

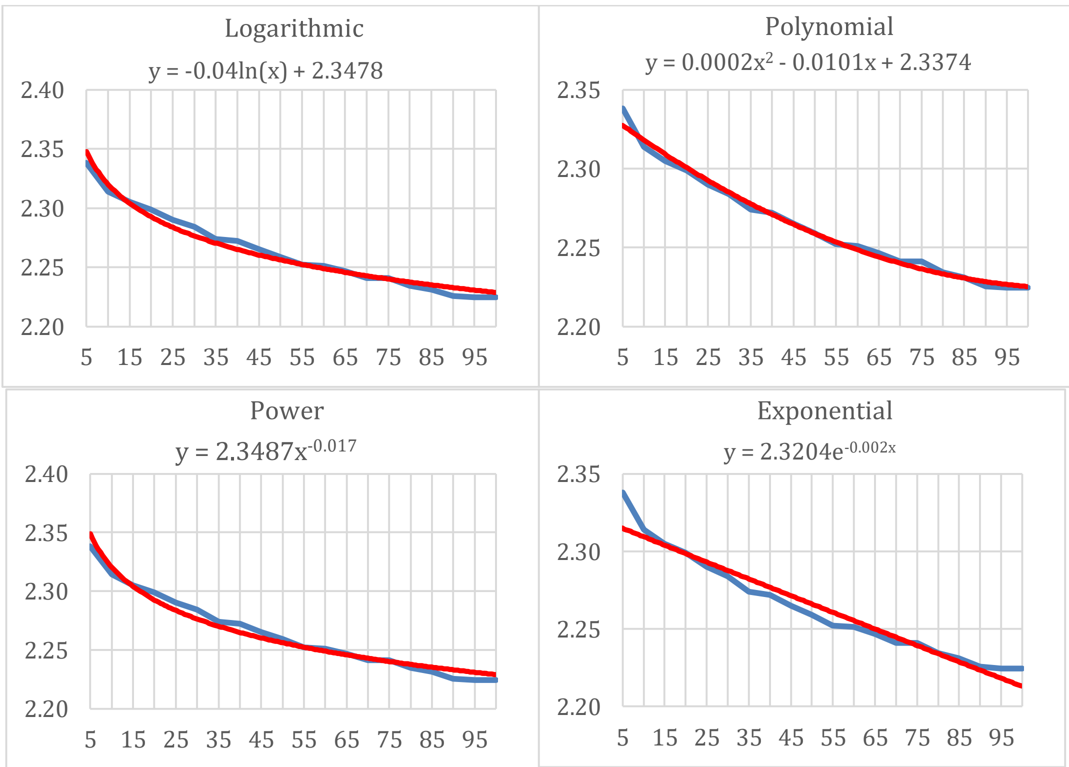

Figure 5.14: High Jump Senior Men

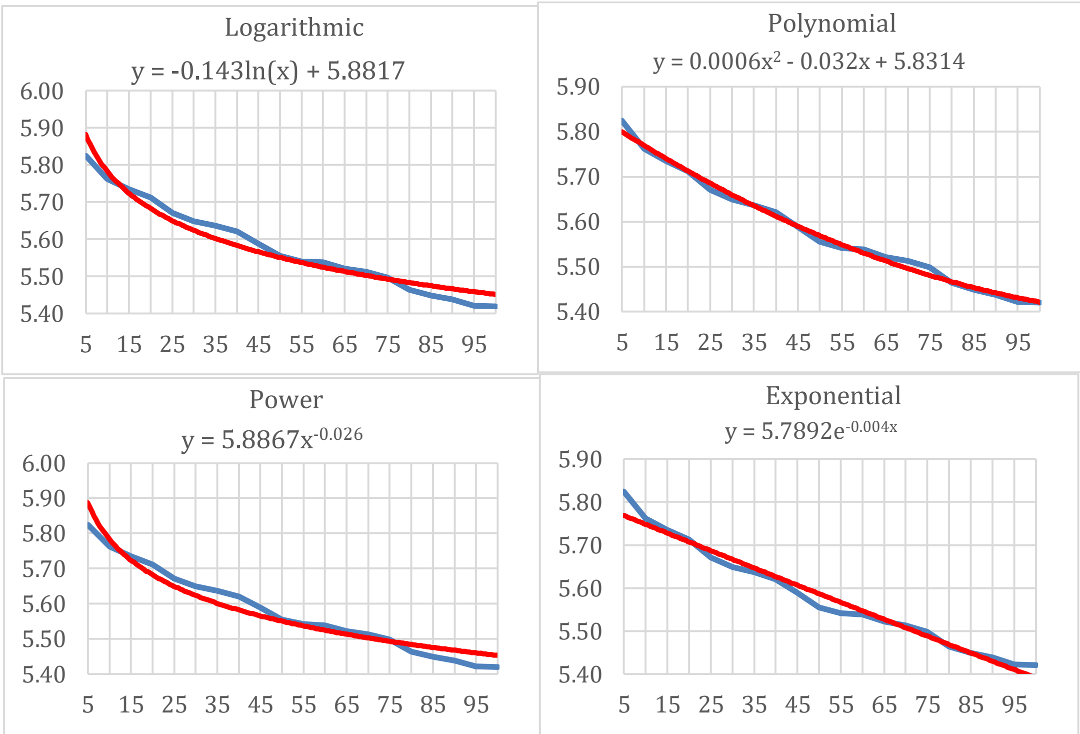

Figure 5.15: Pole Vault Senior Men

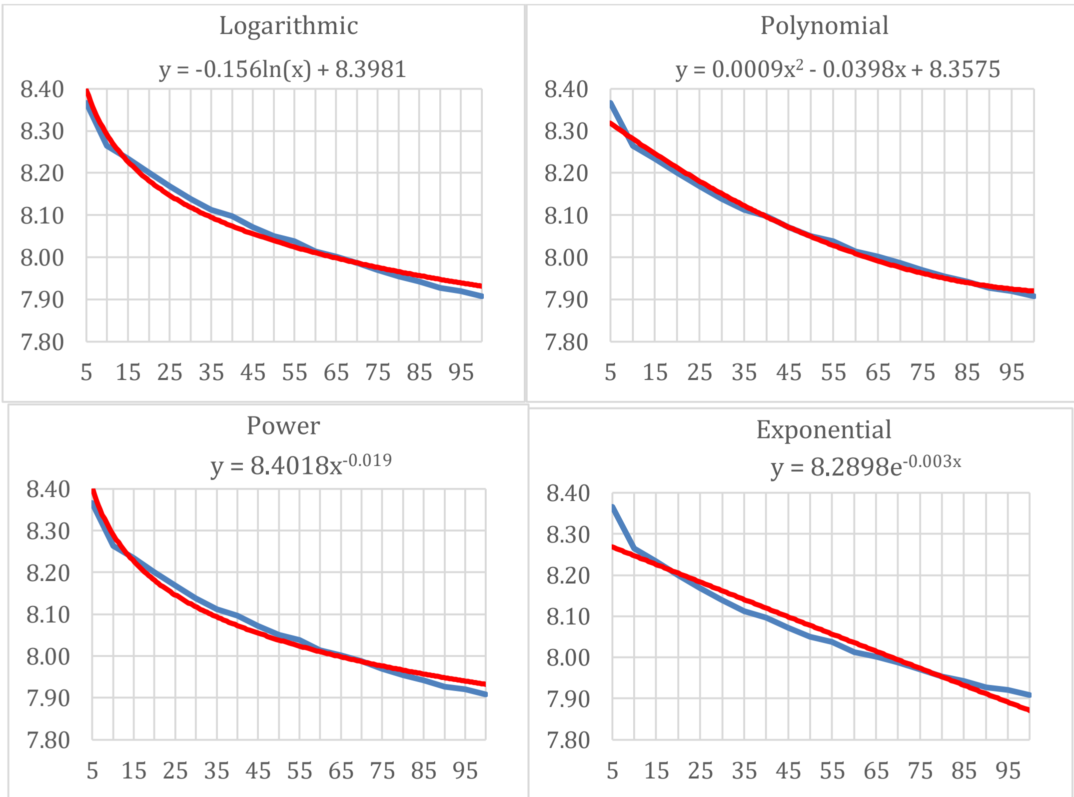

Figure 5.16: Long Jump Senior Men

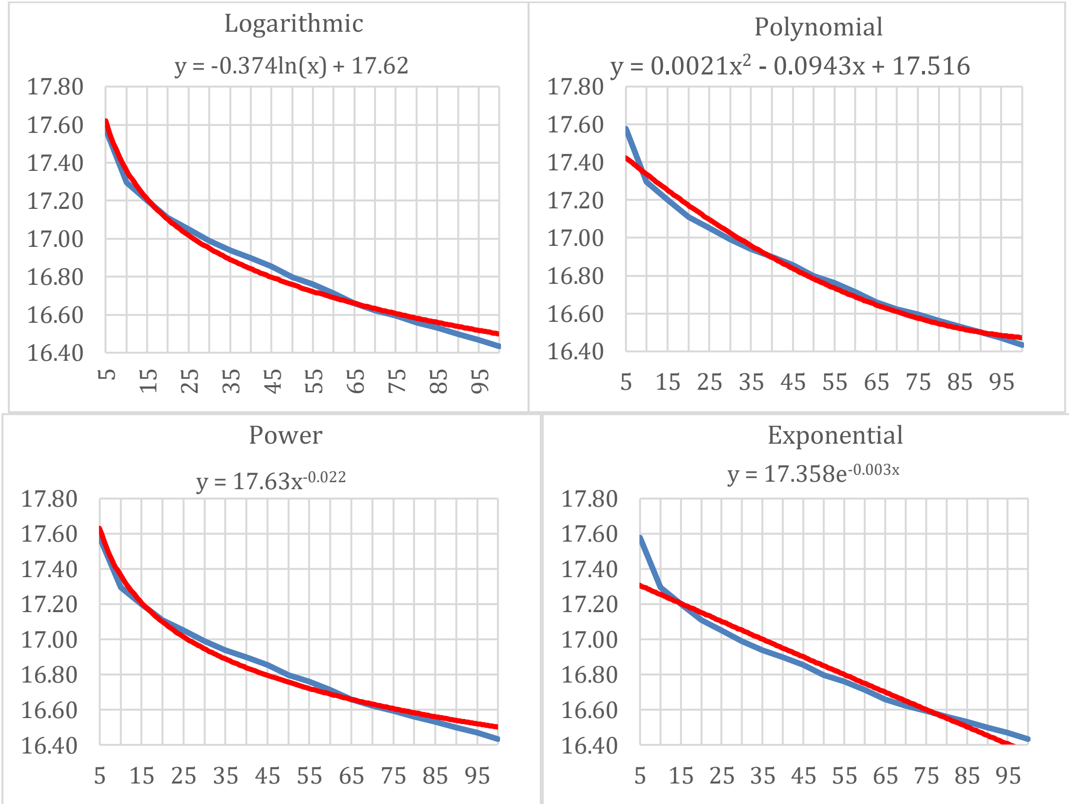

Figure 5.17: Triple Jump Senior Men

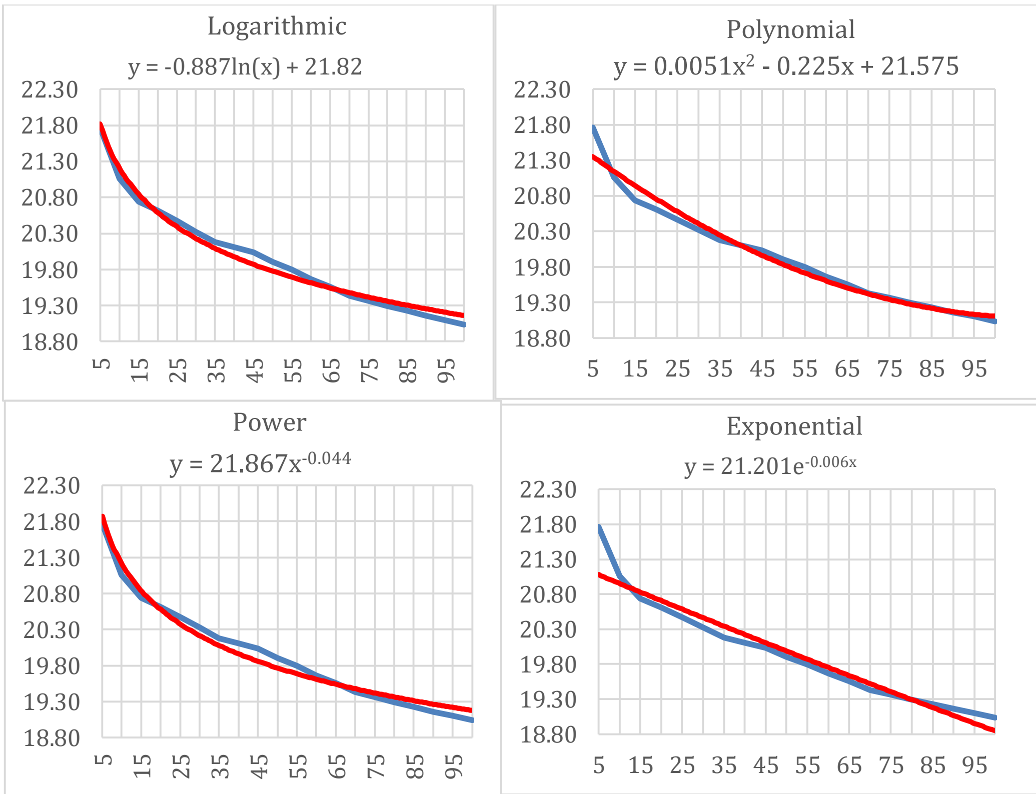

Figure 5.18: Shot Put Senior Men

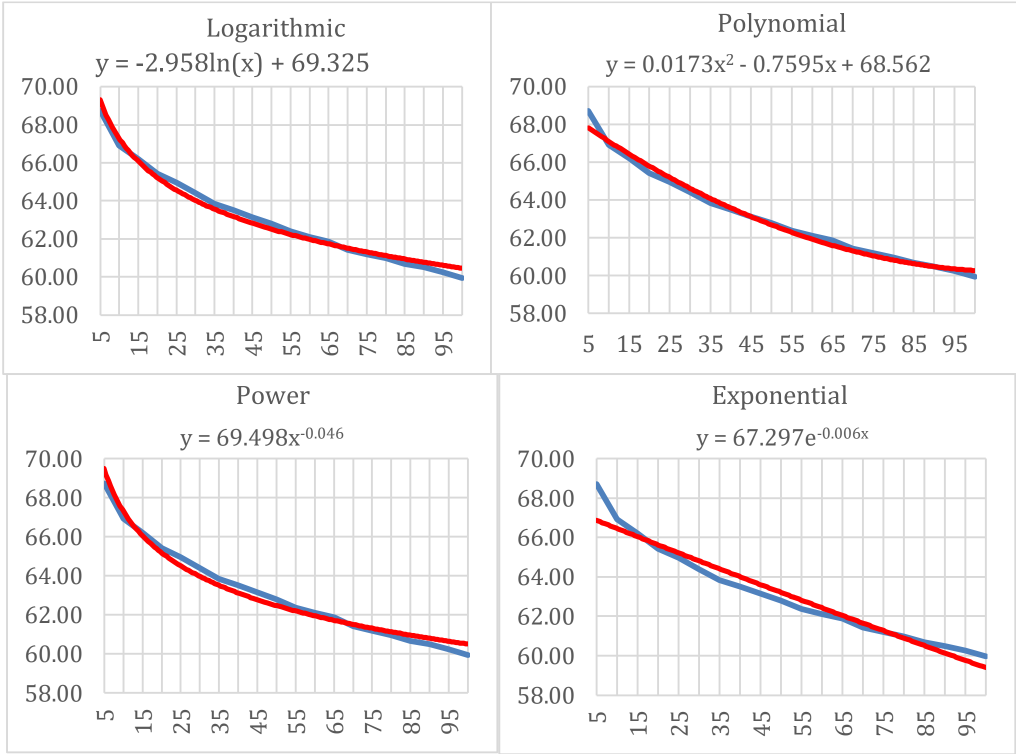

Figure 5.19: Discus Throw Senior Men

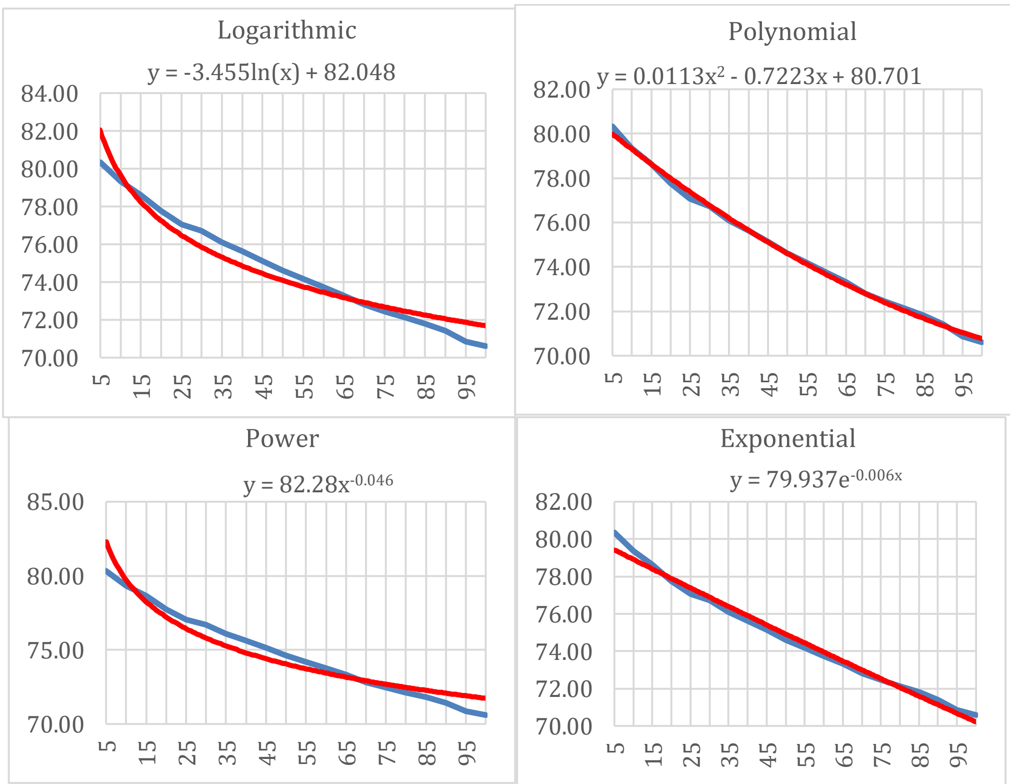

Figure 5.20: Hammer Throw Senior Men

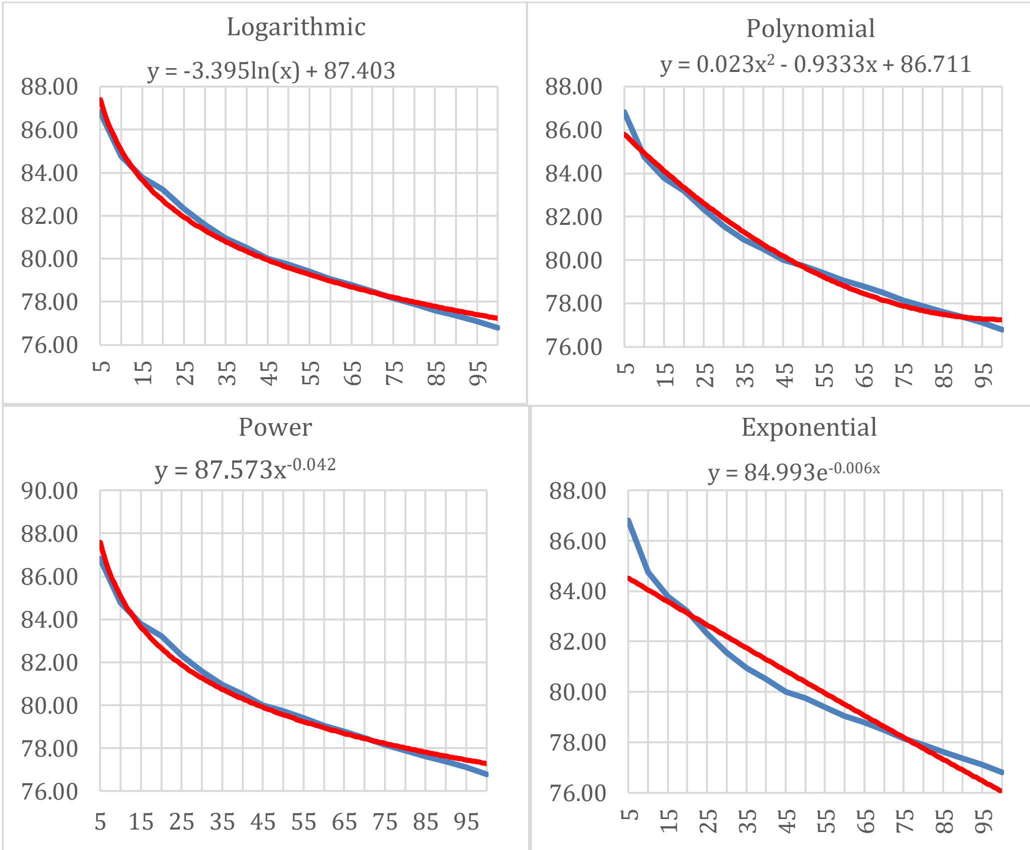

Figure 5.21: Javelin Throw Senior Men

5.3.2 Comparison discussion

All graphs show the data line and the model trend line for each event. The following initial observation can be made from the graphs.

It is clear that the exponential model does not provide a trend line close to the data points. Because of this obvious observation this model will be excluded from further discussions.

As seen in the graphs for 200m, 400m, 3000m, 400mH and 3000mSC, the polynomial model shows a turning point in the trend line. This implies that on the extended trend line, it would be possible to obtain a prediction of increased performance in lower positions. This is obviously not possible and the constants for this model must be reconsidered to prevent this situation in extended results.

There is insufficient data to provide comparison graphs for the 20000 meter walk event. For this and all similar events with insufficient or no data, interpolation and extrapolation will be used to determine standards using data from related events.

A summary of the constants and the confidence indicator for the logarithmic, polynomial and power models is shown in Table 5.7. The last column shows the type of function with the highest confidence indicator for the specific event.

Table 5.7: Statistical constants from graphical models

Senior Men											
Event	Logarithmic: y = a.ln(x)+b			2nd Order Polynomial: y = ax^2+bx+c				Power: y = ax^b			Best fit method
	a	b	Conf	a	b	c	Conf	a	b	Conf	
100m	0.13	9.86	99.6%	0.00	0.04	9.87	98.6%	9.858	0.013	99.6%	Power
200m	0.24	19.94	99.0%	0.00	0.08	19.97	93.4%	19.942	0.012	98.9%	Log
400m	0.45	44.48	97.3%	0.00	0.12	44.57	99.6%	44.483	0.010	97.4%	Poly
800m	1.13	103.29	99.7%	-0.01	0.34	103.43	97.3%	103.300	0.011	99.7%	Power
1500m	2.50	210.31	96.8%	-0.01	0.61	211.02	99.4%	210.340	0.012	96.9%	Poly
3000m	8.45	447.92	97.0%	-0.05	2.28	449.68	99.8%	448.120	0.018	97.2%	Poly
5000m	10.96	771.79	96.0%	-0.05	2.54	775.35	99.4%	771.990	0.014	96.2%	Poly
10000m	29.02	1606.50	96.9%	-0.16	7.35	1613.90	99.6%	1607.100	0.018	97.1%	Poly
110mH	0.19	13.11	99.3%	0.00	0.05	13.15	98.2%	13.109	0.014	99.4%	Power
400mH	0.80	47.90	99.6%	-0.01	0.24	48.01	97.9%	47.916	0.016	99.7%	Power
3000mSC	10.15	482.52	98.1%	-0.06	2.54	485.35	98.6%	482.760	0.020	98.3%	Poly
4x100m	0.62	38.01	99.5%	0.00	0.18	38.11	98.5%	38.017	0.016	99.5%	Power
4x400m	2.67	179.46	98.3%	-0.02	0.79	179.81	99.4%	179.500	0.015	98.4%	Poly
HJ	-0.04	2.35	97.5%	0.00	-0.01	2.34	98.9%	2.349	-0.02	97.3%	Poly
PV	-0.14	5.88	95.0%	0.00	-0.03	5.83	99.2%	5.887	-0.03	94.6%	Poly
LJ	-0.16	8.40	98.1%	0.00	-0.04	8.36	98.7%	8.408	-0.02	97.9%	Poly
TJ	-0.37	17.62	98.3%	0.00	-0.09	17.52	97.8%	17.630	-0.02	98.0%	Poly
SP	-0.89	21.82	98.2%	0.01	-0.23	21.58	97.1%	21.867	-0.04	97.7%	Poly
DT	-2.96	69.33	98.3%	0.02	-0.76	68.56	98.7%	69.498	-0.5	97.8%	Poly
HT	-3.46	82.05	94.0%	0.01	-0.72	80.70	99.7%	82.280	-0.05	93.1%	Poly
JT	-3.40	87.40	99.0%	0.02	-0.93	86.71	98.4%	87.403	-0.05	98.7%	Poly
Average	97.87%			98.48%				97.78%			Poly

The confidence indicator is obtained from the R^2 indicator on the deviations between the actual data and the obtained trend lines.

As no clear single model is indicated in any group of events and the confidence values are close to each other, all three models must be considered in refinements. The following changes in the basic models can be considered:

- Logarithmic model – Use a base different from the natural base *e*.
- Polynomial model – Consider 3rd order model.
- Exponential model – Not much can be done but it may still be used as a component in a hybrid model.
- Combining all three (or a combination of two of them) to create a hybrid model with increased confidence.

5.4 Relation between events

This is the main concern with all existing tables, namely that there is no consistency on the progression between events.

In this section emphasis will be placed on the weighted 5th position as a standard and additional positions will be used as confirmation indicators.

To be able to have the same relation for track events as for field events, track events are used as the distance ran per second of the race. Using this relation slower athletes get lower values and this can then be compared with field events where lower positions are indicated by lower performance values.

This relation is calculated by using the distance of the race and dividing it by the time to complete the race in any position. In this calculation the completion race time will be the weighted averages of each event.

Table 5.8: Speed in meter per second for track events

Position	100m	200m	400m	800m	1500m	3000m	5000m	10000m	110mH	400mH	3000mSC	4x100m	4x400m
5	10.12	10.06	8.95	7.74	7.1	6.65	6.44	6.18	8.37	8.33	6.19	10.5	8.87
10	10.06	9.93	8.93	7.69	7.07	6.61	6.41	6.15	8.31	8.26	6.12	10.41	8.83
15	10.01	9.89	8.91	7.66	7.05	6.58	6.39	6.12	8.27	8.22	6.08	10.34	8.79
20	9.98	9.85	8.88	7.64	7.02	6.54	6.36	6.09	8.24	8.16	6.05	10.31	8.76
25	9.95	9.83	8.86	7.61	7.01	6.52	6.34	6.06	8.22	8.13	6.03	10.27	8.72
30	9.93	9.81	8.85	7.59	7	6.5	6.33	6.05	8.19	8.11	6	10.23	8.69
35	9.9	9.8	8.83	7.58	6.98	6.48	6.32	6.02	8.17	8.09	5.99	10.21	8.68
40	9.88	9.78	8.81	7.57	6.97	6.46	6.31	6.01	8.16	8.07	5.97	10.18	8.66
45	9.87	9.77	8.8	7.56	6.96	6.44	6.3	6	8.14	8.06	5.96	10.17	8.63
50	9.86	9.76	8.79	7.55	6.95	6.42	6.29	5.99	8.13	8.04	5.95	10.15	8.62

Normal running events will be handled first and then the comparative relation between these and events with obstacles (hurdles and steeple chase), walking, and relays will be determined.

Events used in other age groups will be included and values determined using the trend line obtained from the events for senior men.

5.4.1 Track event relations for distances from 50m to 10 000m

Various trends were investigated and the three best fits are shown on the graphical representation (Figure 5.22) using the weighted 5th positions.

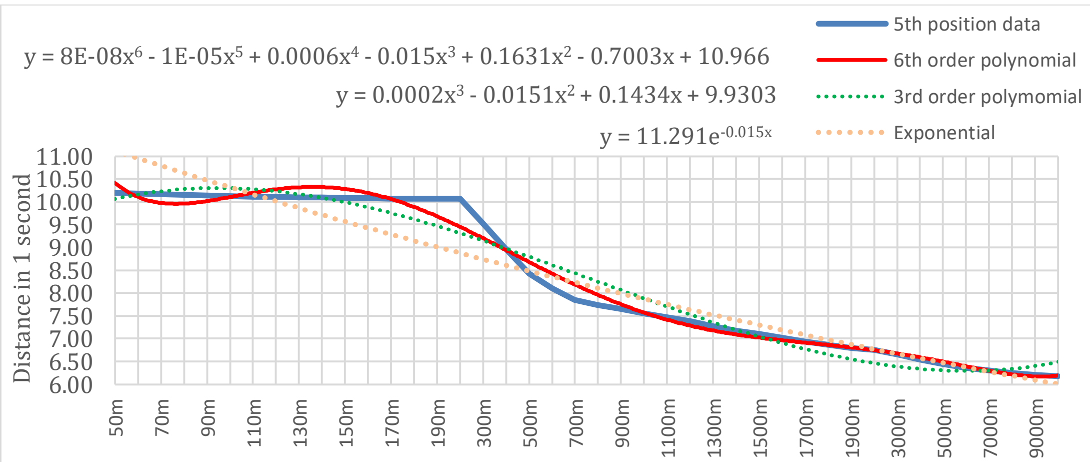

Figure 5.22: Relationship between events for Senior Men

The 6th order polynomial function has a confidence indicator of 98,65% but due to the oscillating nature at the lower end (50m to 100m) and the shape between 500m and 3000m it is questionable.

The 3rd order polynomial has a confidence indicator of 96,63% mostly due to the difference at the 200m event. For the remaining events it appears to be a better fit than the 6th order polynomial.

The exponential function has the lowest confidence indicator of 93,36% but it can still be considered as an option in a hybrid function.

To get better relations events can be grouped as sprints (50m to 200m), intermediate distances (200m to 800m), middle distances (800m to 2000m) and lastly long distances (2000m to 10000m). A trend can then be determined for each group with continuance intercepts at the 200m, 800m and 2000m events.

The following graphs (Figures 5.23 to 5.26) show the group relations. In the separation of groups it is found that any contribution in the polynomials higher than 2nd order becomes negligible. It is thus reasonable to use the more simplistic 2nd order polynomials with a high degree of confidence.

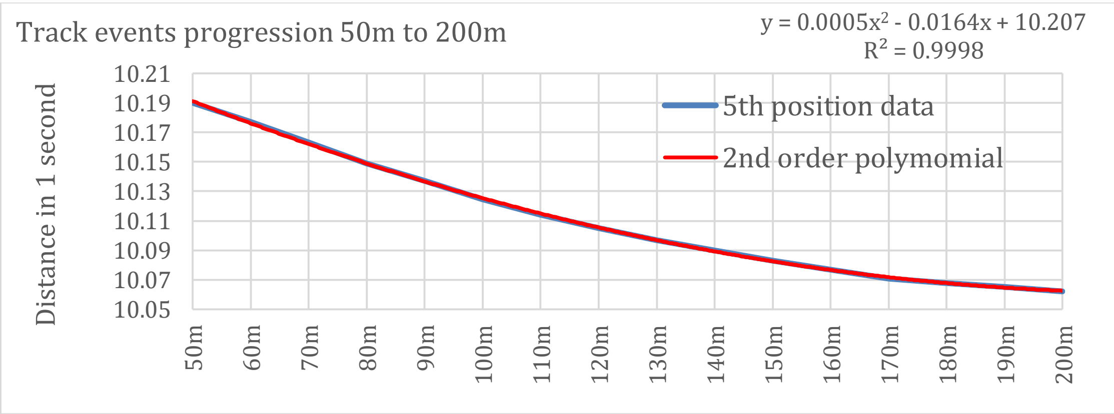

Figure 5.23: Track progression 50m to 200m

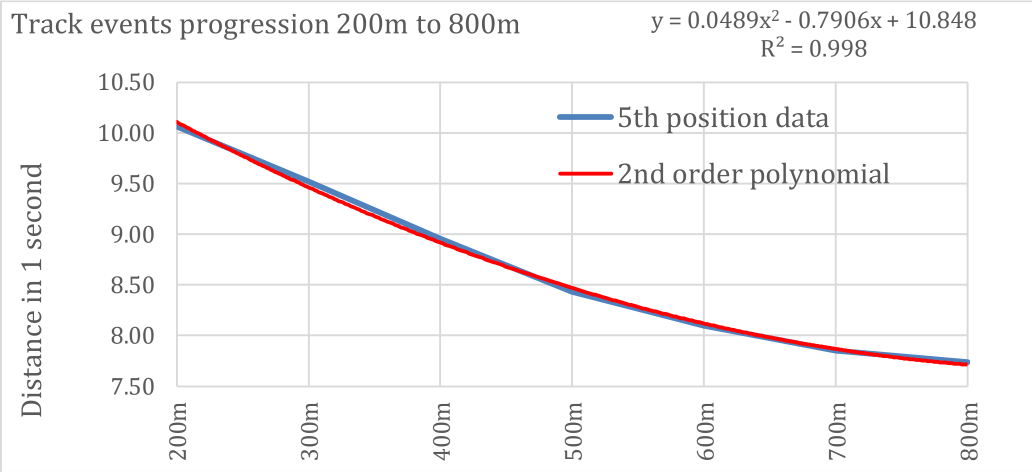

Figure 5.24 – Track progression 200m to 800m

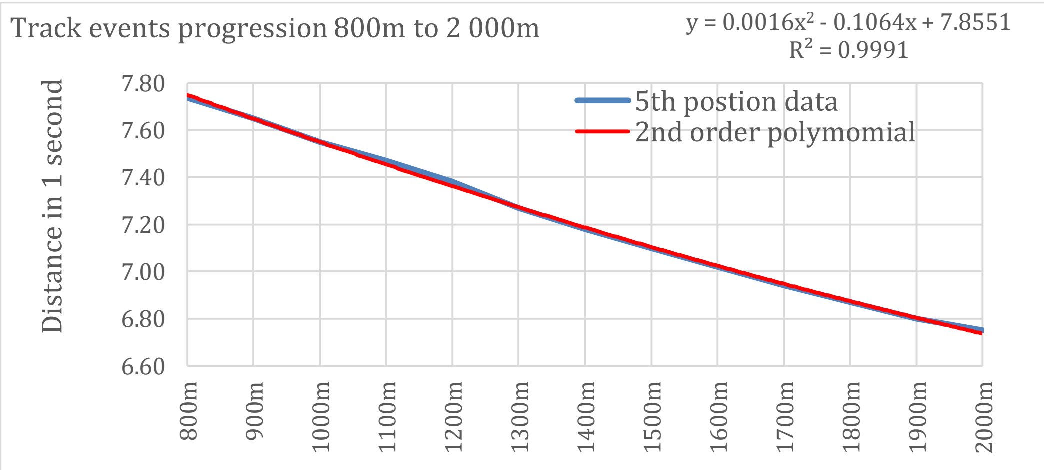

Figure 5.25: Track progression 800m to 2 000m

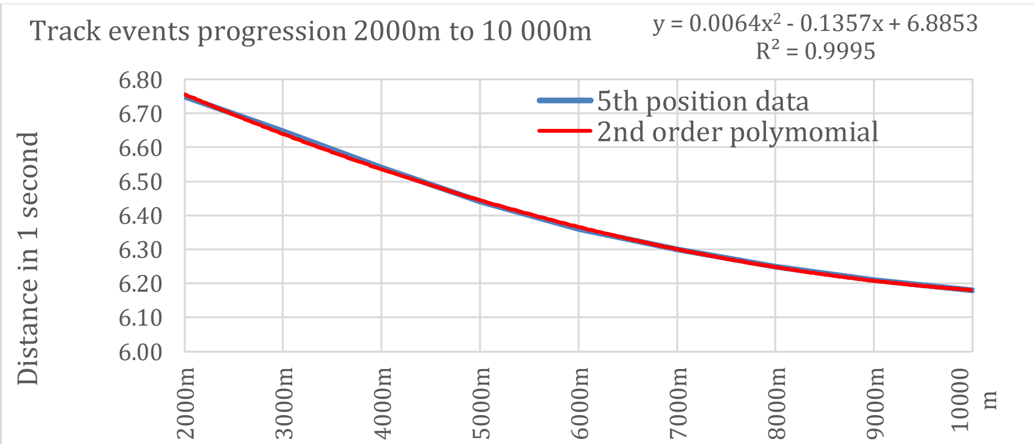

Figure 5.26 – Track progression 2 000m to 10 000m

The expected result of improved confidence is obtained by using the 2nd order polynomials in each group of events. For the test data on senior men these values for the function

$y = a.x^2 + b.x + c$ is given in Table 5.9.

Table 5.9: Progression constants for Senior Men Track events

Group	a	b	c	Confidence
50m to 200m	0,0005	-0,0164	10,207	99,98%
200m to 800m	0,0489	-0,7906	10,848	99,80%
800m to 2000m	0,0016	-0,1064	7,8551	99,91%
2000m to 10000m	0,0064	-0,1357	6,8853	99,95%

These constants may change slightly in the final model to accommodate South African standards. The formula can then be used to set the standards for the 5th position reference for any standard track event.

In the revision cycle of the table standards it will thus only be required to determine the new constants using the values from the new trend lines to change all values in the tables.

5.4.2 Relation between track events and obstacle events

To determine these relations, the hurdle events, steeple chase and race walking events will be considered as sub groups.

As senior men run a 110 meter hurdle, and there is no comparison in track events, the 2nd order polynomial determined in paragraph 5.4.1, together with the constants for 50m to 200m in Table 5.9, is used to determine the 110 meter track standard for the 5th position.

Solving for the 110m mark in $y = 0,0005.x^2 -0,0164.x + 10,207$

gives a value of 10.117 meters per second.

As the height of the hurdles in the 110 meter race and the 400 meter race is different, each event will have a different ratio. The same applies to the steeple chase event.

The ratios to be used to determine the hurdle and steeple chase standards from the track events, provide the multipliers given in Table 5.10.

Table 5.10: Obstacle events multipliers

Event	Track standard	Event standard	Multiplier
110mH	10,117	8,37	0,82732
400mH	8,95	8,33	0,93073
3000mSC	6,65	6,19	0,93082

The same calculations are done for all other obstacle events using the corresponding projected track values.

5.4.3 Race walking events

For senior men there is only a 20 000 meter walk event with not enough raw data available to create graphical representation for this event. The weighted 5th position is 4988,28 seconds (1 hour 23 minutes 8,28 seconds).

A multiplier for this event can be obtained by extending the formula for the track events to 20 000 meters. This provides a standard for the normal track event at 6,617 meters per second compared to 4,01 meters per second for the race walking event. This give a multiplier for race walking events of 0,6060.

This value can't be considered as reliable because of the number of data points available and without real comparative track results. For school meetings, however, there are race walking events ranging from 1500 meters to 20 000 meters and the complete determination of the multiplier(s) will thus be done in the section considering the age differences.

5.4.5 Relay events

A large number of relay events are supported by the IAAF and ASA but only a small selection are used as standard events.

The commonly used standard events at senior level are the 4 x 100 meter and 4 x 400 meter relays.

The following are senior relay events frequently used at international meetings:
4 x 200 meter, 4 x 800 meter, 4 x 1500 meter and a group of medley relays.

The medley relays include:

- 1 000 meter medley consisting of 100 meter, 200 meter, 300 meter and 400 meter legs.
- 1 600 meter medley consisting of 2 x 200 meter, 400 meter and 800 meter legs. This is also referred to as the metric standard relay which was derived from the 1 mile standard relay consisting of 2 x 220 yards, 440 yards and 880 yards (approximately 1 622 meter).
- Various combinations of 2 000 meter relays varying from 4 to 8 legs in the distance.

Standards for the relays can't simply be derived from the base track standards as (a) 3 of the athletes have running starts and (b) within the rules athletes can stretch or shrink the individual legs by using the start and end points of the take-over zones. The fastest athlete in the team can thus run 120 meters on the back leg and the slowest 80 meters on the 3rd leg around the bend. A 4 x 100 meter race can actually consist of (90 + 120 + 80 + 110) meter sections.

It is however true that, similar to hurdles, a multiplier can be defined based on the equivalent track events. These multipliers are shown in Table 5.11.

Table 5.11 – Multiplier values for Senior Men Relays

Event	Base event	Multiplier
4x100m	100m	10,12/10,50 = 0,9638
4x200m	200m	10.06/10.24 = 0,9824
4x400m	400m	8,95/8,97 = 0,9978
4x800m	800m	7,74/7,77 = 0,9971

As can be expected, the longer the distance becomes, the smaller is the effect of the take-over and only relays including legs up to 200m need correction factors. All other relays can be determined directly from the base values or a multiplier of 1 can be applied.

5.4.5 Field events without implements

It is reasonable to expect a correlation between field events without implements and track events. These events are long jump, triple jump, high jump and pole vault. All four of these require a vertical take-off speed as the initial force for the event.

It is expected that the table formula for these events can be the same and closely linked to that of the track events. But, because of technique and style changes in these events it can't be assumed that general changes in track events will reflect corresponding changes in these events. The standards according to the weighted 5th positions must be determined per event and not from a relation formula. The test data values show in Table 5.12 are the weighted 5th position standards for these events.

Table 5.12: Standards for Field events (no implements)

Event	Standard
Long Jump	8,37m
Triple Jump	17,58m
High Jump	2,34m
Pole Vault	5,82m

5.4.6 Field events with implements

The changes in body shape and muscle development with age require that the weight and dimensions of implements must change for athletes in different ages and genders.

Each type of event (shot put, discus throw, hammer throw and javelin throw) will be considered separately. Within each event a relation between the implement differences and age differences will be determined. It will also be determined if the relation for different implements can be standardized.

The determination of ratios for weights that are different from those used by senior men will be done in the section dealing with age differences. For senior men the standards in Table 5.13 will apply.

Table 5.13: Standards for Field events (with implements)

Event	Weight	Standard
Shot Put	7,26 kg	21.76
Discus Throw	2 kg	68.72
Hammer Throw	7,26 kg	80.34
Javelin Throw	2 kg	86.81

5.4.7 Changing the constants for track events

As previously mentioned, the standards and constant values derived for international senior men may be adjusted for South African standards.

The effect of changing the constants in the polynomial $y = a.x^2 + b.x + c$ is shown in the graphs of Figure 5.27. Only the first group of 50 to 200 meter is considered but the same changes are valid for all groups. A change of 30% to the values was used.

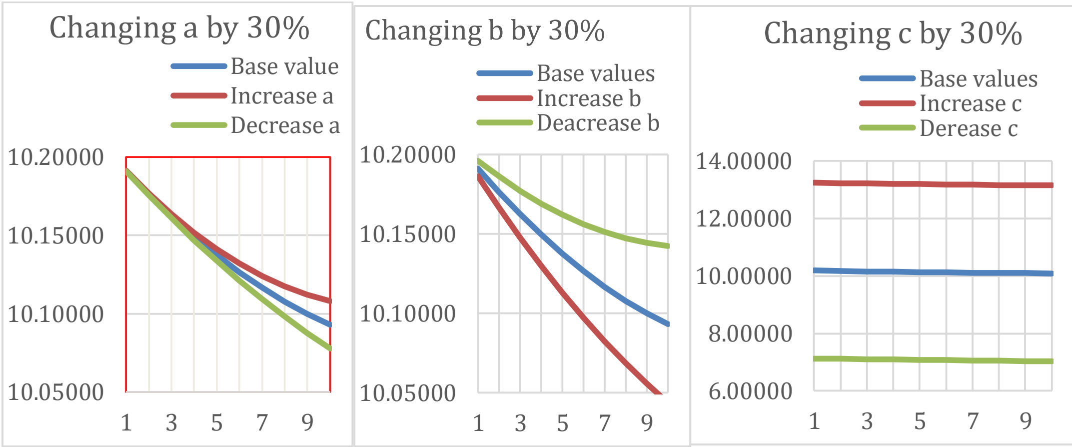

Figure 5.27: Changing the polynomial constants

Changing *a* has an aggressive but small change in the shape at the lower end of the curve. Changing *b* is less aggressive but more pronounced across the range. Changing *c* only shifts the graph with no shape changes. See the attachment "Table generation.xlsx" sheet "Constant Changes".

5.5 Age difference effects for male athletes

The international data only provide three age groups for comparison. These are Senior Men (25 years and older), Junior Men (19 years and younger) and Youth Boys (17 years and younger).

With only 3 data points per event it will not be possible to determine a reliable progression function. South African data will be used from the highest level of competition in the age groups 19, 17, and 15 years for high schools and 13, 12, 11 and 10 years for primary schools. Combined with the South African senior championships this will provide 8 data points per event.

5.5.1 Position progression per event

Firstly it is necessary to confirm that the progression for other ages has the same shape as that of senior men. Only a subset of events where all three ages participate will be used and a full list of all events can be found in the attachment “Comparing Progressions.xlxs”. Figures 5.28 to 5.31 is a subset of the total comparison done and this subset is sufficient to support the conclusions based on the full comparison.

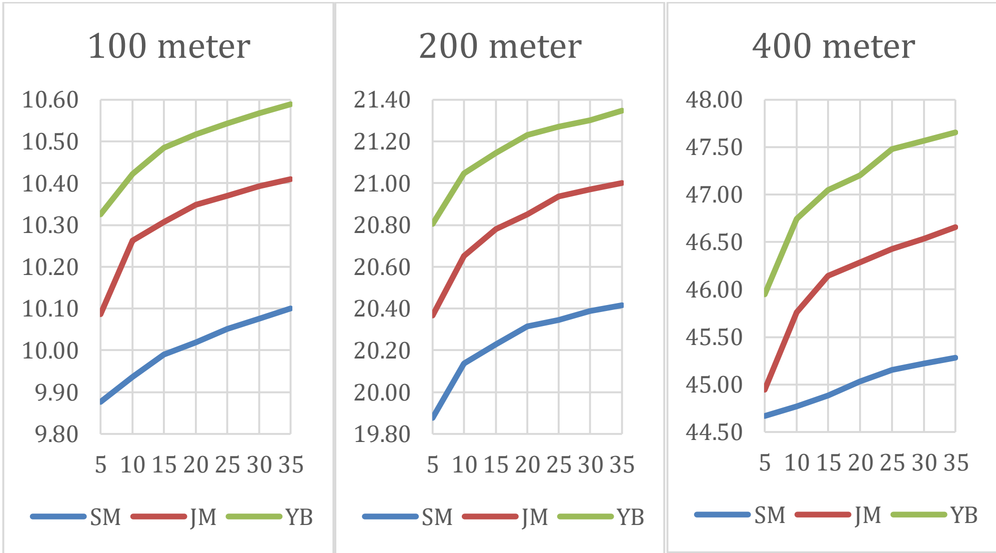

Figure 5.28: Comparing Male Sprint events

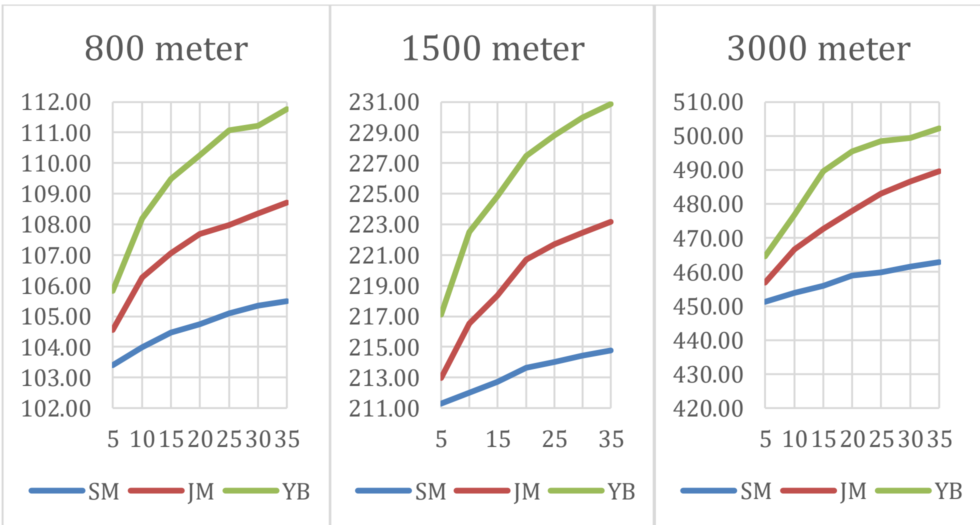

Figure 5.29 – Comparing Male Middle distance events

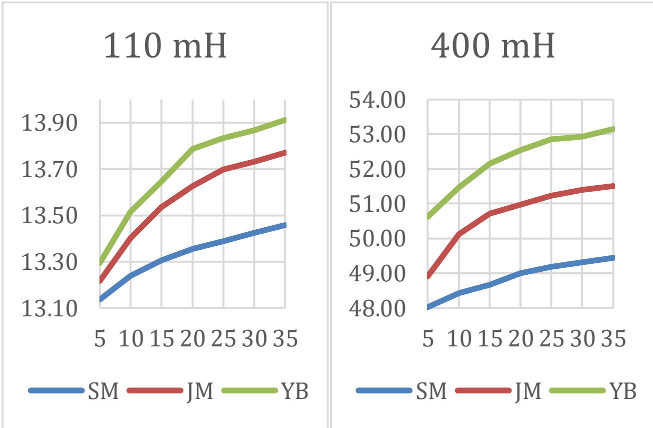

Figure 5.30 – Comparing Male Hurdle events

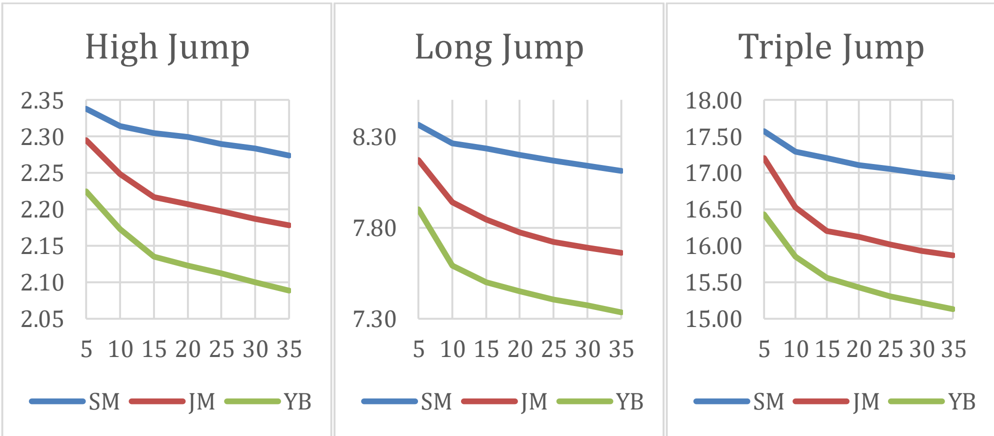

Figure 5.31 – Comparing Male Field events (no implements)

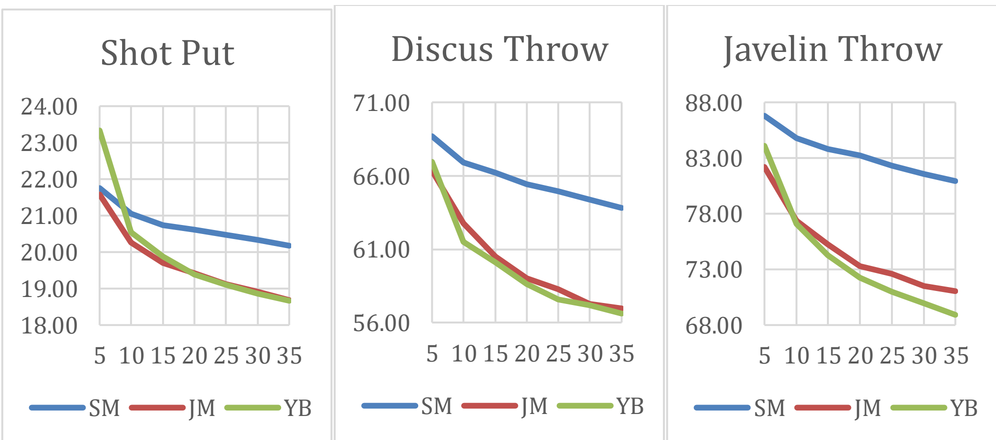

Figure 5.32 – Comparing Male Field events (with implements)

All the graphs show a consistent shape of performance increase as the position increases. It also suggest a consistent pattern of performance increase as the age increases except in the last set of graphs where implements are involved. This deviation is because of different weights and the decrease in weight of the implement is reflected in a longer distance achievement.

5.5.2 Age progression within specific events

Considering only the 5th position weighted averages and using South African data, Table 5.14 reflects the corresponding performances obtained for male athletes.

Table 5.14 – South African 5th position averages

South African Male weighted performances by age (25 = Senior)								
Event	**25**	**19**	**17**	**15**	**13**	**12**	**11**	**10**
80m							10.97	11.29
100m	10.4	10.81	10.92	11.35	12.24	12.82	13.4	13.87
150m						19.12		
200m	20.8	21.83	22.27	22.97	24.61			
400m	46.21	48.94	49.33	52.02				
800m	104.49	114.1	116.34	120.78	132.62			
1200m						219.54	224.03	238.5
1500m	219.97	237.84	243.53	251.86	270.74			
3000m	535.55							
5000m	484.71	921.24	532.55	554.82				
10000m	815.66							

The only event with available data in all age groups is the 100 meter sprint which will be used as the standard reference. As the main objective of the tables is to provide performance evaluations for schools, the age group for junior men (19 years) will be used as a reference.

By inserting calculated values for the other ages between 6 and 25 years, the relation in Figure 5.33 is found:

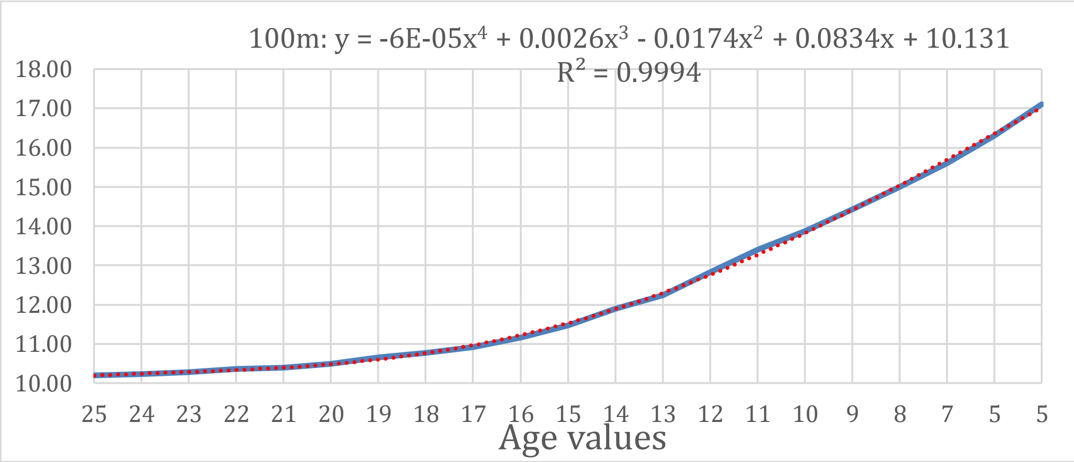

Figure 5.33: South African 100 meter progression (Performance)

The graphical result provided a best fit 4th order polynomial given by:

$$y = -6.10^{-5}.x^4 + 0,0026.x^3 - 0,0174.x^2 + 0,0834.x + 10.131$$

The confidence factor for this function is 99,94%

As an alternative the speed in meter/second can be used. This gives the result shown in Figure 5.34.

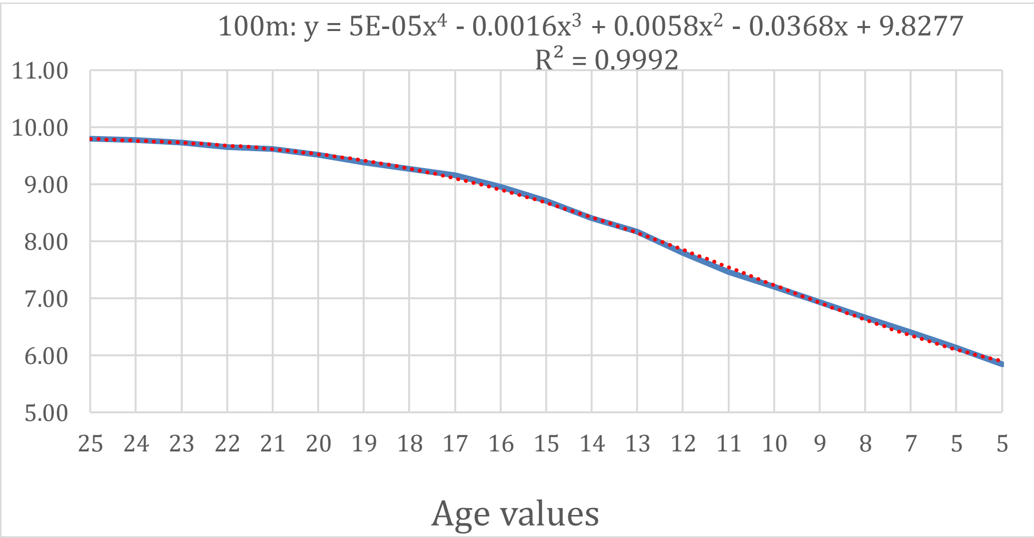

Figure 5.34: South African 100 meter progression (Speed)

The corresponding 4th order polynomial is:

$$y = 5{,}10^{-5}.x^4 - 0{,}0016.x^3 + 0{,}0058.x^2 - 0{,}0368.x + 9{,}8277$$

The confidence indicator for this function is 99,92%

In both cases it appears as if the 4th order is so small that it can be neglected but the 3rd order polynomial has a turning point at the 24 year age which will produce faster times for this age than required for senior men.

The remaining track events (with fewer data points) will be used to confirm or modify the trend function. Again, to be able to produce functions comparable to field events, the speed functions will be used for track events.

The most common track events with sufficient data points are the 100, 200, 400, 800 and 1500 meter events. Using these events, with calculated data for events without values, the graphs shown in Figure 5.35 were obtained:

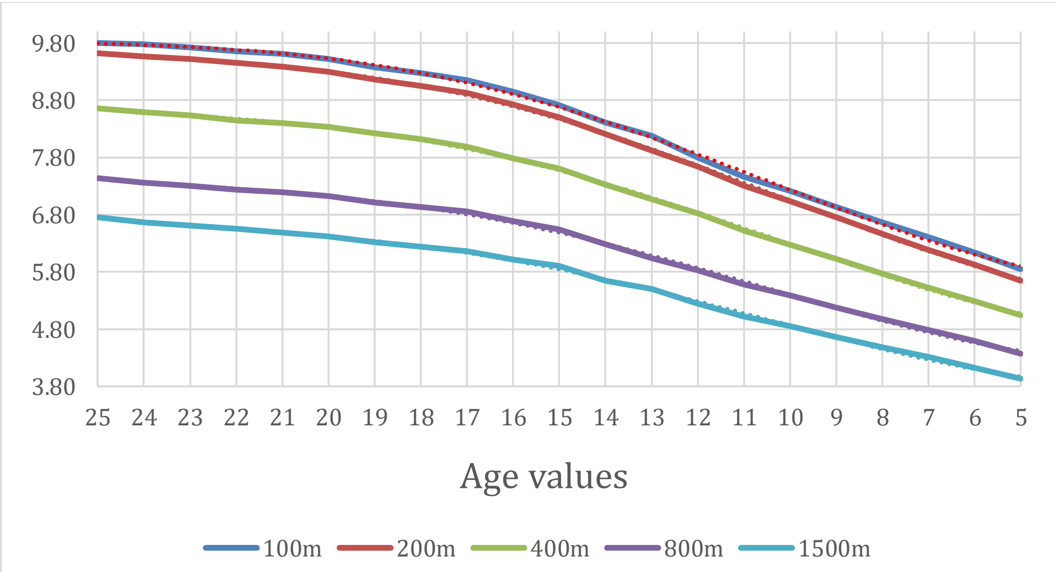

Figure 5.35: Determination graph for age progression

The constants of these 4^{th} order polynomials are:

Table 5.15: Polynomial constants for age progression

Event	*a*	*b*	*c*	*d*	*e*	Confidence
100m	5.10^{-5}	-0,0016	0,0058	-0,0368	9,8277	99,92%
200m	4.10^{-5}	-0,0016	0,0071	-0,0542	9,6598	99,96%
400m	4.10^{-5}	-0,0016	0,0094	-0,0706	8,7069	99,95%
800m	4.10^{-5}	-0,0016	0,0113	0,0815	7,4928	99,89%
1500m	4.10^{-5}	-0,0016	0,0131	0,0995	6,8344	99,90%
Averages	4.10^{-5}	-0,0016	0,00934	0,06852		

The derived formula will use the averages for *a*, *b*, *c* and *d* with *e* as offset value which will depend on each event. During a revision of values the offset must be adjusted to reflect the correct performance of each event at the 5^{th} weighted average for junior men. This value can be automatically calculated from this polynomial.

Age progression formula:

$$y = 4.10^{-5}.x^4 – 0,0016.x^3 +0,00934,x^2 -0,06852.x + e$$

Where x = 26 – age group value and *e* is the event offset constant determined from the speed of the event for senior men (age group 25 giving $x = 1$).

Table 5.16: *e* Values for South African events

Event	Performance	Speed	*e*
100m	10.66	9.3809	9.664
200m	21.83	9.1634	9.4465
400m	48.94	8.1736	8.4567
800m	114.10	7.0113	7.2944
1500m	237.84	6.3068	6.5899
5000m	921.24	5.4275	5.7106

In the final formulation only the performance at 100 meter will be used and the group event polynomials will be used to find the performance values for all other track events without obstacles.

5.5.3 Age progression for hurdle events

The technical standards for hurdles are shown in Table 5:17.

Table 5.17 – Technical standards for hurdles

Age group	Race distance	Hurdle height	Number of hurdles	Distance between hurdles		
				Start to first	Mid race	Last to finish
Boys 10 and 11	70 m	68 cm	8	10 m	7 m	11 m
Boys 12	75 m	76,2 cm	8	11 m	7,5 m	11,5 m
Boys 12	150 m	68 cm	7	23 m	19 m	13 m
Boys 13	80 m	76,2 cm	8	12 m	8 m	12 m
Boys 13	200 m	68 cm	10	16 m	19 m	13 m
Boys 14	100 m	76,2 cm	10	13 m	8,5 m	10,5 m
Boys 14	300 m	76,2 cm	7	50 m	35 m	40 m
Boys 15	100 m	84,0 cm	10	13 m	8,5 m	10,5 m
Boys 15	300 m	84,0 cm	7	50 m	35 m	40 m
Boys 16	110 m	84,0 cm	10	13,72 m	9,14 m	14,02 m
Boys 16 to 18	400 m	84,0 cm	10	45 m	35 m	40 m
Boys 17 and 18	110 m	91,4 cm	10	13,72 m	9,14 m	14,02 m
Boys 16 to 18	400 m	84,0 cm	10	45 m	35 m	40 m
Junior Men - Boys 19	110 m	99.5 cm	10	13,72 m	9,14 m	14,02 m
Junior Men - Boys 19	400 m	91,4 cm	10	45 m	35 m	40 m
Senior Men	110 m	106,7 cm	10	13,72 m	9,14 m	14,02 m
Senior Men	400 m	91,4 cm	10	45 m	35 m	40 m

As can be seen in the table, the race distances, number of hurdles and hurdle heights are adjusted according to the development of athletes in different age groups. With the formulae developed at this stage, it is possible to generate age standards for all the hurdle distances but these will only apply to the height for junior men. Standard multipliers, based on the 5 year average data must be developed for the other hurdle heights.

As there are only reliable data at certain ages, the standards for other ages must be extrapolated from the available reliable data. Even the reliability of the standard where data is available is uncertain as in the 150, 200 and 300 meter hurdle events where only one age is running these events.

It is reasonable to accept that within a specific age group the performance change for a corresponding height change will be proportional to the ratio of the heights of the hurdles. The function:

$$Height\ Multiplier = \left(\frac{Height\ of\ hurdle}{Maximum\ hurdle\ height}\right)^{k}$$

will be used to accommodate this effect. The value of *k* will be adjusted during a revision period based on the standard 5 year averages available during the revision.

5.5.4 Age progression for steeple chase and race walking events

As these are long distance events (1 500 to 20 000 meters), the only adjustment required will be a multiplier based on the standard 5 year average compared to the same 5 year average for the corresponding track distance.

5.5.5 Age progression for field events

These events will be subdivided as jumping and throwing events. Each of these groups relies on different techniques and in the case of throwing events also implement weight changes.

5.5.6 Age progression for jumping events

Using the available 5 year average data, a similar polynomial to that used for track events can be determined to predict the standards for unavailable data in other age groups and to adjust the available data to more acceptable values. The graphical determination of the function is shown in Figure 5.36.

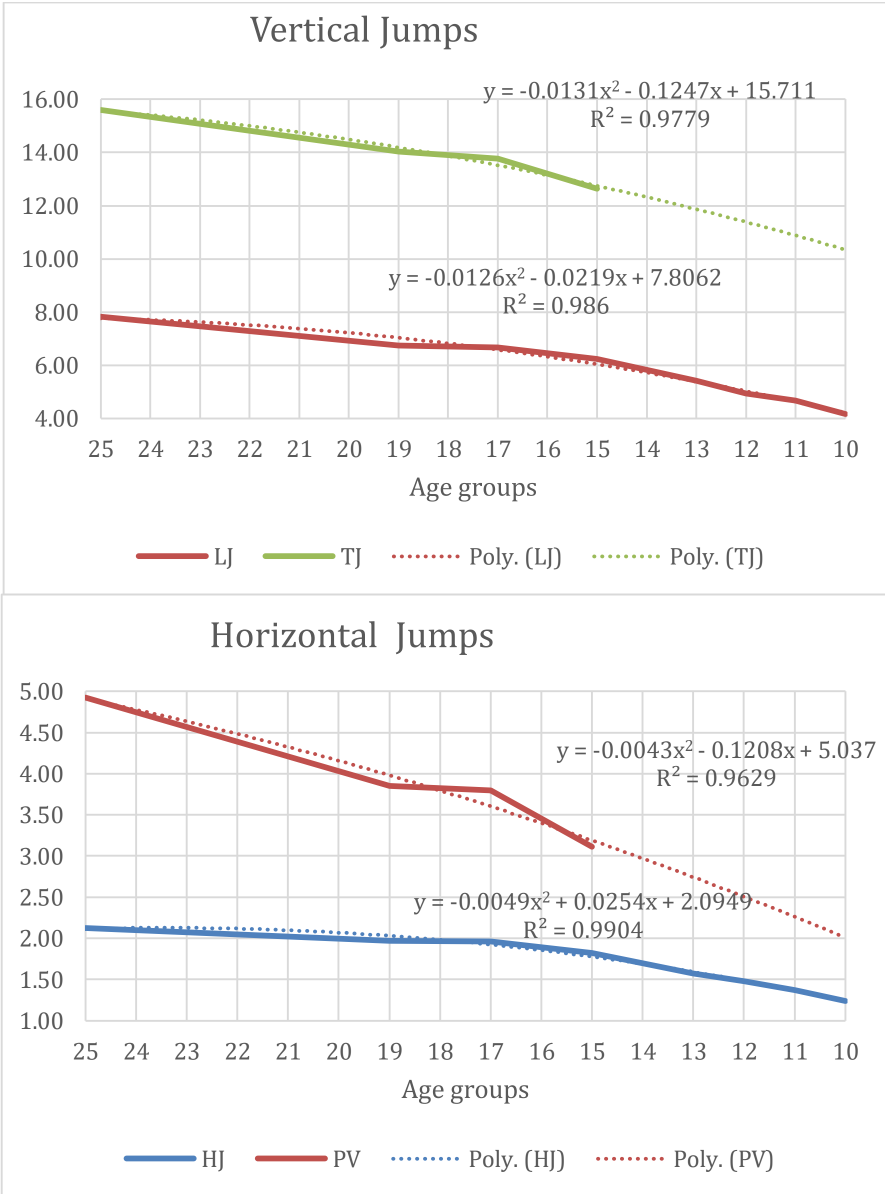

Figure 5.36: Age difference for Jump events

As can be seen from the graphs, pole vault is an event that is not done by a large number of athletes and it is still emerging as a competition event in South African schools. It can be expected that the standard may change more than those for other events during the periodic revisions of the tables. The same applies to a lesser degree to the triple jump event.

The above calculators will be used to determine the polynomial constants for the revision periods in the table generation spreadsheet. For these events the 2nd order polynomial provides better results than the 4th order polynomial used for track events.

5.5.7 Age progression for throwing events

As all these events involve implements that change with age differences, multipliers will be used to adjust the standards for the different weights within an event. Similar to the jump events, a set of 2nd order polynomials will be derived from the junior men standards for each event.

Multipliers are determined by comparing the predicted standard with the junior men implements to the standard performance in the highest available age group using a different implement.

Table 5.18 shows the technical standards that are currently in use for male athletes:

Table 5.18: Technical standards for throwing events

Age group	Shot	Discus Throw	Hammer	Javelin Throw
Boys 10 and 11	2,0 kg	-	-	-
Boys 12	3,0 kg	750 g	-	500 g
Boys 13	4,0 kg	1,0 kg	-	600 g
Boys 14 and 15	4,0 kg	1,0 kg	4,0 kg	600 g
Boys 16 and 17	5,0 kg	1,5 kg	5,0 kg	700 g
Boys 18 and 19	6,0 kg	1,75 kg	6,0 kg	800 g
Senior Men	7,26 kg	2,0 kg	7,26 kg	1,0 kg

The following basic assumptions will be applied to determine the ratio values for these events.

- For any specific implement, if the same implement is used by athletes of different ages but the same ability, the performance of younger athletes will be less than that of older athletes.

- Within any specific age group and event, the same athlete will have lower performances as the weight of the implement increases.

- The performance ratio change will be proportional to the implement weight ratio.

To determine the actual values of the influence of weight differences the following multiplier formula will be used:

$$Weight\ Multiplier = \left(\frac{Weight\ of\ implement}{Maximum\ implement\ weight}\right)^k$$

where *k* will be adjusted during the revision to cover the range from maximum to minimum implement weights.

Considering the above arguments and using the current available data, the trends shown in Figures 5.37 and 5.38 were observed.

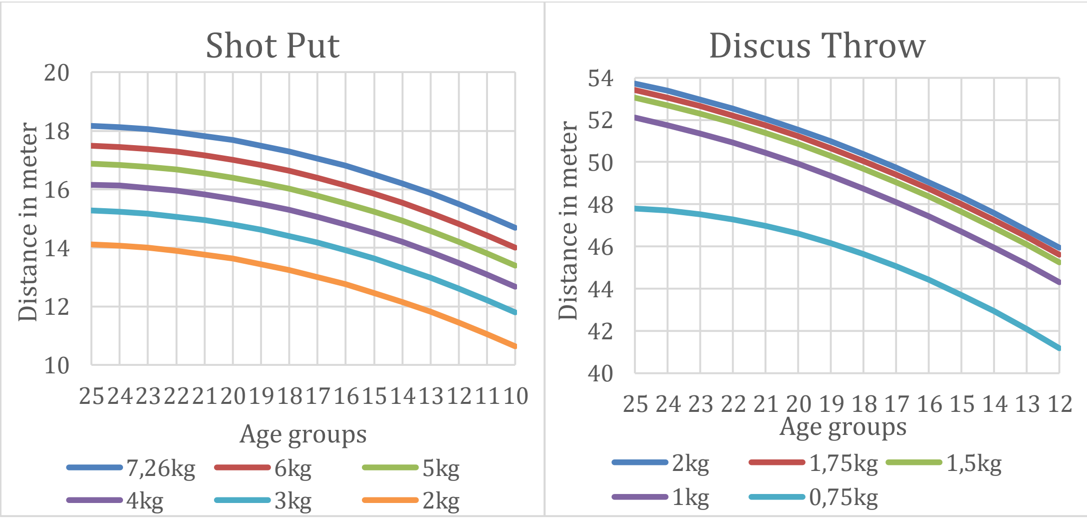

Figure 5.37: Age progression for Shot Put and Discus Throw

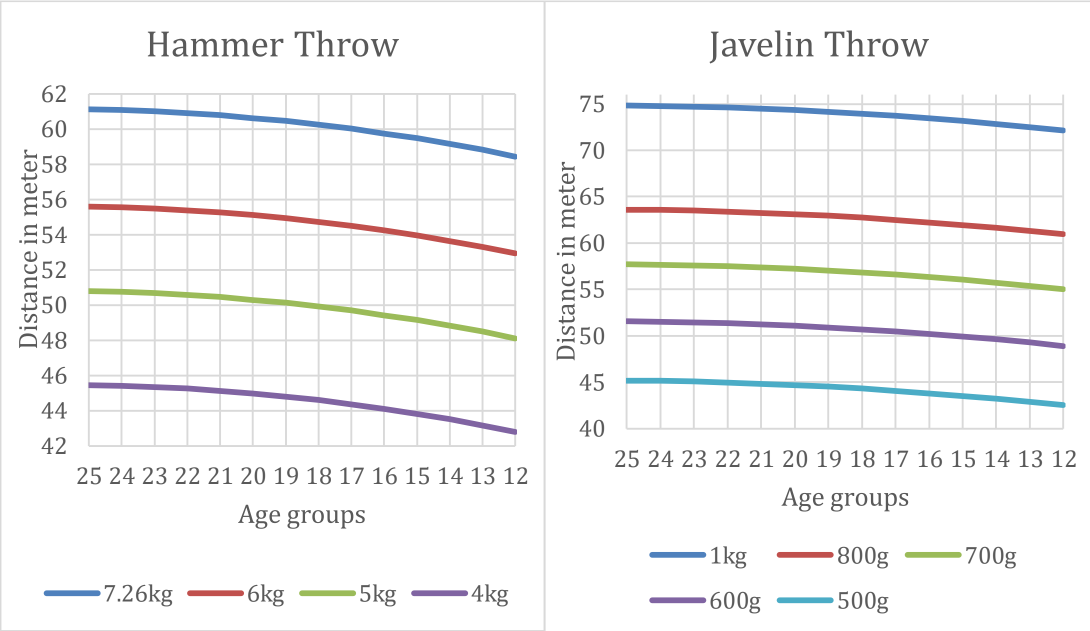

Figure 5.38 – Age progression for Hammer and Javelin Throw

From the graphs the following conclusions can be made:

- Within an event the different implements have the same progressive change and only a constant shift exists between the graphs.
- Each type of event requires different skills and natural ability, using coordination of different muscle groups and thus the rate of change between ages is different.
- The difference of performance for a specific age using different implement weights is event dependent.

In the table generation revision each event will be handled separately based on the reliable components of the 5 year average data.

5.5.8 Gender differences

To determine the relation between the performances of male and female athletes it is necessary to consider the physical development of athletes.

Due to physical strength and body dimensions, it is accepted that on senior level, male athletes will perform better than female athletes in all events. This statement is not necessarily true for younger athletes.

To verify whether the statement is true for all events a comparison will be done on a selection of representative events. These comparisons are shown in Figure 5.39.

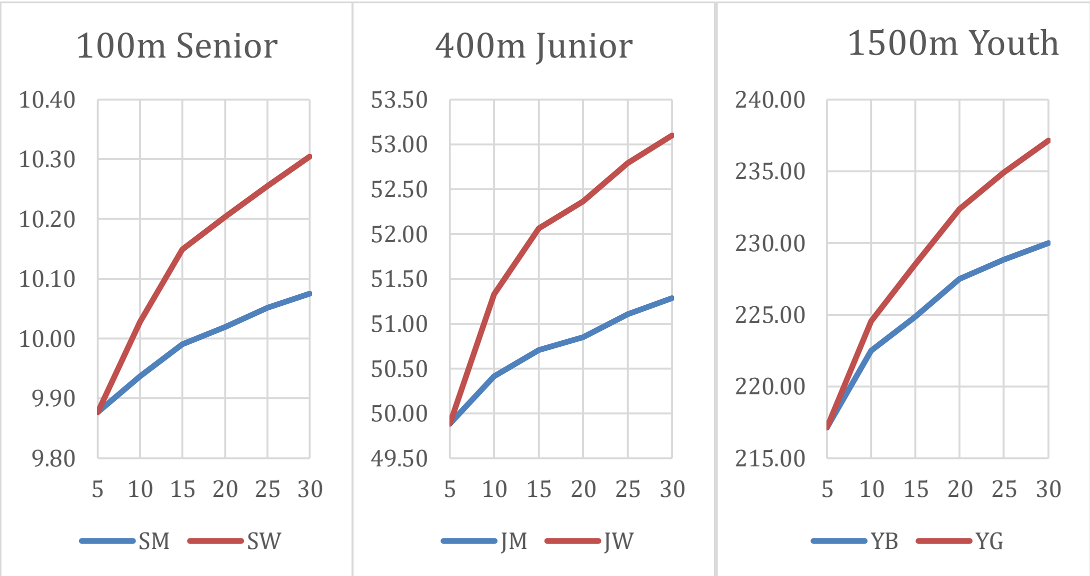

Figure 5.39: Comparing Male and Female performances

In these graphs the performance of female athletes was normalized by setting the 5th position performance of female athletes equal to that of male athletes. It can be seen that at the lower positions (up to 30th position), the performance of female athletes deteriorates faster than that of male athletes. This tendency is applicable to different events as well as different age groups. The same tendency is observed in all available events.

It is thus clear that although the shape of the curves obtained for men and those for women follow the same basic functions, the rate of change is different. A separate set of functions and event relations, using the same principles can be derived for female athletes. It will then be possible to define multipliers for the different constants and in this way female performances can be derived from the male standards. The freedom to be able to make small adjustments will be included by allowing for the same range changes as is available for male athletes.

5.6 Generation of comparative tables

The standards developed provide the basis for comparison of performances at different ages and genders in different events. The formula that generates the table values will only be valid if the standards used in each event are at the same level.

5.6.1 Table criteria

Different criteria must be set to generate tables that are acceptable, useful and easily interpretable.

- The table is set to a range from 0 to 1000 points. This is selected in order to be able to have a large variation of performances within the table and to be able to interpret the values. By simply dividing the point by 10 it can be interpreted as a percentage performance.

- The tables must reflect the progressive rewarding of increased performances.

- The table must be flexible to extend beyond the 1000 point mark while maintaining the progressive properties of performance increases.

- The weighted average will be set as the 900 point reference.

- The current records in each event should be approximately 1000 points. This requirement can't be enforced but it can only be used as a check value. The reason is because records are quite often extreme performances as is evident when considering the achievement dates of records. Some of these have been set more than 10 years ago. Using an extended range records should be between 950 and 1200 point but for most records they should be in a narrower band between 950 and 1050 points.

- Athletes eligible for inclusion in a provincial team should be above the 750 point mark.

- Athletes participating at a provincial meeting should be above the 600 point mark.

- The 0 point should be set at a reasonable value without being so low that it will never be used. These will not be an exact value but rather intuitive values that can be based on the following broad statements:

    - For track events an athlete can walk the distance at a reasonably fast pace.

    - For jump events the distance/height that can be achieved from a standing position.

    - For throwing events the distance that can be achieved from a standing position.

For the last criteria, to obtain reasonable values for the lower end (near 0 point mark) a value of half the standard value can be used. In the case of track events based on speed, this implies twice the standard performance.

5.6.2 Table formula for 100 meter Junior Men

Using the criteria it is required to inspect the data to determine possible data points and then formulate progressive curves parameters that will reflect this data. Only the 100 meter event for junior men (boys 19 years) will be used for the initial formulation.

This group is selected because this is where the largest set of South African data is available and this data was obtained from meetings with trusted results.

The formula will then be applied to the standards of other ages and events for confirmation of the formula.

Additional software will be used to achieve data mining to obtain performances that can be used to satisfy the criteria and to assist in the determination of curve functions.

To be able to use a single formula for track and field events, all track events will be converted to speed values instead of using the actual performance values.

Analysis of the South African schools data for the 100 meter junior men (boys 19) provided the performances in Table 5.19. The record information is that which was available during the 2012 athletic season. The low performances are the 5 year low values from 2007 to 2012.

Table 5.19: SA Schools results averages

100m Junior Men (19)			
Level	Points	Performance (seconds)	Speed (m/s)
SA Record	1000	10.06	9.94
5th position average	900	10.66	9.38
SA Meeting low	750	11.52	8.86
Provincial Meeting low	600	13.15	8.10
Record times 2	0	20.12	5.56

Using this data and applying it to obtain trend information, the graphical results in Figure 5.40 were found.

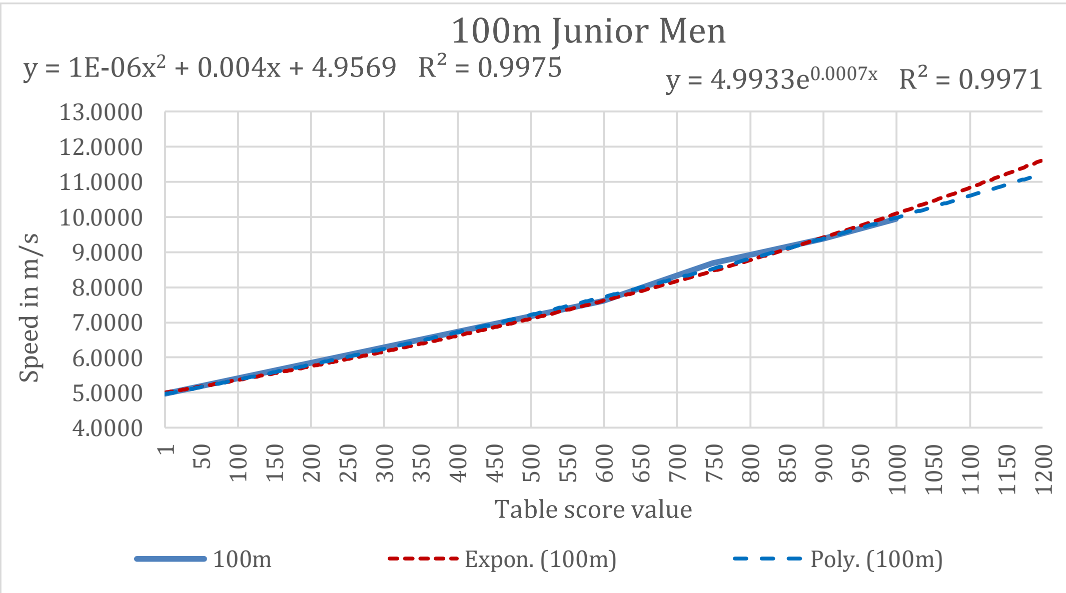

Figure 5.40: SA Schools 100m junior men averages

The table score values were extended to 1200 points to be able to verify criteria 5 (the requirement that the table must be able to extend beyond 1000 points for exceptional performances). From the derived trend lines, the projected data at the original test points changes to the values shown in Table 5.20.

Table 5.20: Projected performances for 100m junior men

100m Junior Men (19)							
Level	Original statistical data			Exponential		Polynomial	
	Points	Perf	Speed	Speed	Perf	Speed	Perf
SA Record	1000	10.06	9.94	10.06	9.95	9.96	10.04
5th position average	900	10.66	9.38	9.38	10.67	9.37	10.68
SA Meeting low	750	11.52	8.86	8.44	11.85	8.52	11.74
Provincial Meeting low	600	13.15	8.10	7.60	13.16	7.72	12.96
Record times 2	0	20.12	5.56	4.99	20.03	4.96	20.17

At the standard 5th position both formulae are close to the required standard. Above this value the exponential curve is more aggressive and overshoots the SA record by a considerable margin while the polynomial is again close to the required value.

The turning point of the polynomial can be determined from the first derivative of the function. This gives *0,00002.x + 0,004 = 0* and thus the turning point will be at *x* = -2000 points. As all performances below the 0 point mark will be assigned a 0 value, the turning point is outside the range of the table scores and it will have no effect on the range of calculations.

The performance predicted by the exponential and the polynomial functions for the 1000 point reward is 9,96 seconds. This is faster than the current world record of 10,01 set by Darrel Brown of Trinidad during a meeting in Paris on the 24th of August 2003. The predicted points for this world record, using both formulae give a table value of 992 points.

The current South African record will be given 983 points by the exponential function and 984 points using the polynomial function.

5.6.3 Alternative functions for 100m junior men

As both the generated trend functions provide acceptable results below the 900 point mark but unacceptable results above this value, adjustments will be required before a single function can be selected.

The following options were considered and rejected:

The linear model does not reward increased performances progressively.

The logarithmic, power and higher order polynomial functions were tested and all of these, based on the selected test data, provided incorrect representations as can be seen in Figure 5.41.

Figure 5.41: Alternative 100m functions

What is however useful when considering these functions is that the common value for all functions is found at the 800 point table value. This suggests that the standard should be shifted to the 800 point mark rather than the 900 point mark. But, because the 5th position average is used as standard, the number of performances expected above this performance does not warrant a 200 point interval above this value.

From these arguments and analysis of the data, the alternative of using a hybrid model with the same function but different constants pivoting at the 900 point mark becomes more practical. Above the 900 point mark a more aggressive progression will be used to increase performance rewards and below this point a less aggressive progression to ensure that acceptable lower performances are included.

5.6.4 Selection of the table function

The exponential function is more aggressive in rewarding porformance and will thus be the most likely final function.

The only other consideration is the spread of the performances from 0 to 1000 points. Using the natural base (*e*) does not give the required spread and it will be required to adjust the function from $y = a.e^{b.x}$ to $y = a.b^{c.x}$ If *b* > *e* then the spread increases but the aggressiveness for performances above 900 points becomes excessive.

To solve this problem a hybrid solution is used. For performance below the 900 point standard a value of *b* > *e* will be used and for performances above 900 points a value of *b* < *e* will be used. The lower range value of b will be selected to provide a 0 point performance approximately half of the standard performance at 900 points. The upper value will be selected to have the current record at about 1000 points. The value of a in both sections will be adjusted to reflect the same standard value at 900 points.

This hybrid adjustment is shown in the graph of Figure 5.42.

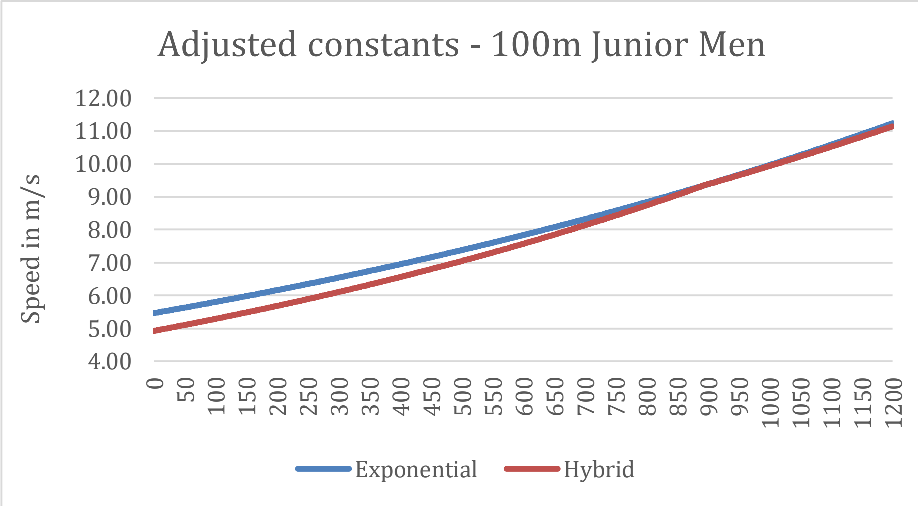

Figure 5.42 – Hybrid exponential function for 100 meter Junior Men

In the model the variable *b* was adjusted continuosly until the required results were obtained. In the graph it can be seen that using *b* = 3,3 for the lower section, it extends the 0 point to a performance of 20,31 seconds compared to the standard at 900 points of 10,66 seconds. This conforms to the original aim of having the 0 mark at 2 times the speed required at the 900 point standard. Using *b* = 2,6 for the upper section gives a 1000 point value of 10,7 seconds compared to the current record of 10,6 seconds. This satisfies the requirement of having the 1000 point mark close to the record values.

5.6.5 Verification of the table function for track events

To verify the validity of the selected function it must be applied to the range of track events and age groups. This is done by selecting test points for the 100, 400 and 1500 meter events and in the age groups junior men (19), youth boys (17) and boys 15 years. These test points have been selected to ensure that sufficient test data is available for all test points. The test results are shown in Table 5.21.

Table 5.21: Formula verification for track events

Factor	100 meter - Male			400 meter - Male			1500 meter - Male		
	Age 19	Age 17	Age 15	Age 19	Age 17	Age 15	Age 19	Age 17	Age 15
a (p > 900)	5.5999	5.4663	5.1996	4.8788	4.8402	4.5899	3.7646	3.6767	3.5593
a (p < 900)	4.9234	4.806	4.5715	4.2894	4.2555	4.0355	3.3099	3.2325	3.1293
Ratio	1,17396	1,17396	1,17396	1,17396	1,17396	1,17396	1,17396	1,17396	1,17396
b (p > 900)	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
b (p < 900)	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
c	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Record	10.06	10.18	10.79	45.91	46.27	48.74	224.41	229.5	237.74
Rec Points	1001	1022	1008	1011	1012	1014	1001	1004	999
1100	9.505	9.737	10.236	43.638	43.986	46.385	212.075	217.148	224.308
1000	10.066	10.311	10.840	46.213	46.582	49.122	224.588	229.961	237.543
900	10.660	10.920	11.483	48.940	49.330	52.020	237.840	243.530	251.560
800	11.451	11.731	12.333	52.575	52.994	55.883	255.503	261.615	270.242
600	13.215	13.538	14.232	60.673	61.157	64.492	294.861	301.915	311.871
400	15.251	15.623	16.425	70.020	70.577	74.426	340.282	348.423	359.912
200	17.600	18.030	18.955	80.806	81.449	85.891	392.700	402.095	415.354
0	20.311	20.807	21.875	93.253	93.996	99.122	453.193	464.034	479.336
0 Ratio	1.905	1.905	1.905	1.905	1.905	1.905	1.905	1.905	1.905

All of the events and age groups display a spread of 1,905 (0 point performace = 1,905 times slower than the standard) and all records are in an acceptable band near 1000 points. If required, the spread can be adjusted by changing the "*b*" (base) values. Adjusting the value for the lower section (3,3) will affect the minimum performance (0 points) that will be included and changing the upper section (2.6) will influence the performance value at the 1000 point mark.

The only change between events is the "*a*" (multiplier) value and this change follows the polynomial previously developed for age differences. The ratio between the two values is found to be constant at 1,137396 for all events and thus, using this multiplier, the full range can be generated.

5.6.6 Verification of the table function for Field events

To verify the tables for field events long jump, shot put and javelin throw will be used for the same age groups. These three events represent all types of field events with sufficient data to be used as test points.

Table 5.22: Formula verification for field events

Factor	Long Jump			Shot Put			Javelin Throw		
	Boys 19	Boys 17	Boys 15	Boys 19	Boys 17	Boys 15	Boys 19	Boys 17	Boys 15
a (p > 900)	1.5639	1.5477	1.4481	3.8994	3.6491	3.3619	14.5804	13.1138	11.5684
a (p < 900)	3.5425	3.5057	3.2801	8.8326	8.2658	7.6150	33.0263	29.7043	26.2038
Ratio	0.4415	0.4415	0.4415	0.4415	0.4415	0.4415	0.4415	0.4415	0.4415
b (p > 900)	15	15	15	15	15	15	15	15	15
b (p < 900)	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
c	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Record	8.09	7.74	6.96	19.24	19.48	20.51	72.36	79.33	71.37
Rec Points	1011	991	966	982	1031	1113	986	1108	1120
1100	9.342	9.245	8.650	23.292	21.798	20.082	87.094	78.334	69.102
1000	7.941	7.859	7.353	19.799	18.529	17.070	74.033	66.586	58.739
900	6.750	6.680	6.250	16.830	15.750	14.510	62.930	56.600	49.930
800	6.283	6.218	5.818	15.667	14.661	13.507	58.580	52.687	46.478
600	5.445	5.388	5.041	13.575	12.704	11.704	50.760	45.655	40.274
400	4.718	4.669	4.368	11.763	11.008	10.142	43.985	39.561	34.899
200	4.088	4.046	3.785	10.193	9.539	8.788	38.114	34.280	30.240
0	3.542	3.506	3.280	8.833	8.266	7.615	33.026	29.704	26.204
0 Ratio	0.525	0.525	0.525	0.525	0.525	0.525	0.525	0.525	0.525

Due to record values which caused very high table points, the top section (above 900 points) required a big spreading change. This spreading factor of 15, compared to 2,6 for track events, is used for all field events.

The bottom range is the same for track and field events. In all events this range provide a 0 point performance of approximately half of the standard performance.

5.6.7 Verification of the table function for gender changes

As already established in paragraph 5.5.8, the difference is a factor change which is constant throughout the range of all events and age groups.

It will thus be sufficient to demonstrate that the function for female athletes is consistent with that of male athletes by considering one track event and one field event. Considering the available data, the 100 meter track event and the shot put field event will be used. The age group for youth athletes (17 years) will be used.

Table 5.23 – Function verification for gender changes

Factor	100 meter		Shot Put	
	Boys 17	Girls 17	Boys 17	Girls 17
a (p > 900)	5.466325	5.110500	3.649148	4.283980
a (p < 900)	4.806000	4.493158	8.265766	9.703738
Ratio	1.137396	1.137396	0.441477	0.441477
b (p > 900)	2.6	2.6	15.0	15.0
b (p < 900)	3.3	3.3	3.3	3.3
c	0.0006	0.0006	0.0006	0.0006
Record	10.18	11.15	19.48	22.37
Rec Points	1022	981	1031	1017
1100	9.737	10.415	21.798	25.590
1000	10.311	11.029	18.529	21.752
900	10.920	11.680	15.750	18.490
800	11.731	12.548	14.661	17.212
600	13.538	14.480	12.704	14.914
400	15.623	16.711	11.008	12.924
200	18.030	19.285	9.539	11.199
0	20.807	22.256	8.266	9.704
0 Ratio	1.905	1.905	0.525	0.525

The information in this table confirms that the function is consistent for female athletes using the same base and exponential constants. The only change is as expected, in the multiplier constant "*a*", which is in line with the findings in paragraph 5.5.8.

5.6.8 Inverse table function

During a meeting the performance of a specific athlete is available and the point score is required. This can be obtained by using the inverse function.

Starting from:

$$Performance = a.b^{c.Point\_score}$$

derive that the inverse function is given by:

$$Point\ score = \frac{\log(^{Performance}/_{a})}{c.\log(b).}$$

This formula can then be used in conjunction with the corresponding constants and keeping in mind that the performance must be compared to the standard to select the correct set of constants.

5.6.9 Hand timing changes

For statistical correctness and acceptability all track events must be timed using electronic timing equipment. All the tables will thus reflect performances applicable to electronic time measurements with accuracy of 2 decimal places.

At most school meetings electronic timing is not available and timekeepers use handheld stopwatches to determine the performances. To be able to convert these times to equivalent electronic times the reaction time of the timekeepers must be considered. This reaction time depends on the distance between the timekeeper and the starter. Hand times will consistently be slower than the electronic time.

From practical experience the IAAF has set the following adjustments.

For events from 60 meters to 200 meters, hand times are adjusted by adding 0,24 seconds.

For 300 meters and 400 meters, hand times are adjusted by adding 0,14 seconds. For all other track events no adjustment is done.

Because of the margin of error in hand timing, all such results are rounded up and used with 1 decimal accuracy. This implies that readings of 13,11 and 13,19 will both be used as 13,2 seconds. The athlete is awarded the slowest 1 decimal performance.

5.6.10 Height above sea level adjustments

Athletes participating in track events at altitude will experience difference in performance due to atmospheric pressure and oxygen level changes. The IAAF prescribe adjustments for these changes.

Table 5.24 – Height above sea level adjustments (track only)

E vent	Height above sea level in meters										
	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
60m	0.04	0.04	0.05	0.05	0.05	0.06	0.07	0.07	0.07	0.08	0.08
80m	0.06	0.06	0.06	0.07	0.07	0.08	0.09	0.09	0.1	0.1	0.1
100m	0.07	0.07	0.08	0.09	0.09	0.1	0.11	0.11	0.12	0.13	0.13
150m	0.11	0.11	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.2	0.21
200m	0.14	0.15	0.17	0.18	0.2	0.21	0.22	0.24	0.25	0.27	0.28
300m	0.22	0.24	0.26	0.28	0.31	0.33	0.35	0.37	0.39	0.42	0.44
400m	0.29	0.32	0.35	0.38	0.41	0.44	0.47	0.5	0.53	0.56	0.59
600m	0.15	0.29	0.08	-0.31	-0.55	-0.66	-0.77	-0.88	-0.99	-1.1	-1.21
800m	0	-0.25	-0.5	-1	-1.5	-1.75	-2	-2.25	-2.5	-2.75	-3
1000m	-0.07	-0.1	-0.64	-1.29	-1.93	-2.25	-2.57	-2.89	-3.21	-3.54	-3.86
1200m	-0.14	-0.18	-0.79	-1.57	-2.36	-2.75	-3.14	-3.54	-3.93	-4.32	-4.71
1500m	-0.25	-0.5	-1	-2	-3	-3.5	-4	-4.5	-5	-5.5	-6
2000m	-0.33	-0.67	-1.33	-2.67	-4	-4.67	-5.33	-6	-6.67	-7.33	-8
3000m	-0.5	-1	-2	-4	-6	-7	-8	-9	-10	-11	-12
5000m	-0.75	-1.5	-3	-6	-9	-10.5	-12	-13.5	-15	-16.5	-18
10000m	-1.5	-3	-6	-12	-18	-21	-24	-27	-30	-33	-36
4x80m	0.22	0.24	0.26	0.28	0.31	0.33	0.35	0.37	0.39	0.42	0.44
4x100m	0.28	0.32	0.35	0.38	0.41	0.44	0.47	0.5	0.53	0.56	0.59
70mh	0.05	0.05	0.06	0.06	0.06	0.07	0.08	0.08	0.08	0.09	0.09
75mH	0.05	0.05	0.06	0.07	0.07	0.08	0.08	0.08	0.09	0.1	0.1
80mH	0.06	0.06	0.06	0.07	0.07	0.08	0.09	0.09	0.1	0.1	0.1
90mH	0.06	0.06	0.07	0.08	0.08	0.09	0.1	0.1	0.11	0.12	0.12
100mH	0.07	0.07	0.08	0.09	0.09	0.1	0.11	0.11	0.12	0.13	0.13
110mH	0.08	0.08	0.09	0.1	0.1	0.11	0.12	0.12	0.13	0.14	0.14
150mH	0.11	0.11	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.2	0.21
200mH	0.14	0.15	0.17	0.18	0.2	0.21	0.22	0.24	0.25	0.27	0.28
400mH	0.29	0.32	0.35	0.38	0.41	0.44	0.47	0.5	0.53	0.56	0.59

All adjustments are in seconds and must be applied to the electronic time result. Venues lower than 1000 meter altitude have no adjustments and any venue higher than 2000 meter altitude uses the same adjustment as for 2000 meter. No intermediate calculations are done and a venue at an altitude of 1460 meter will use the values for 1400 (to 1499) meters.

In an automated system the height adjustments can be included to generate a set of tables for a specific venue. The adjustments for steeple chase and race walking is available in the full adjustment table.

5.7 Summary

After considering various models it was determined that the speed per meter of the different events on the track can be related by using a second order polynomial. Multipliers were generated for race walking, relays, steeple chase and hurdle events.

A fourth order polynomial was developed to determine the standards for all other age groups based on the results for senior athletes.

Field events without implements are related to the track events and for all field events the same function as for track events can be used to determine the standards.

To accommodate the differences in hurdle heights and implement weights multipliers were found based on the ratio of the differences in these measurements.

To accommodate the differences between male and female athletes either a multiplier can be used or different function constants can be derived from corresponding statistical data.

The spread of points from 0 to 1000 within all events are determined by a hybrid exponential function with the 0 point performance approximately half of the 900 point standard and records close to the 1000 point marks. All track events use the same set of constants and all field events a second set of constants.

A summary of all derived functions and the current set of constants can be found in chapter 7.

Chapter 6: Contribution and relevance

6.1 Contribution to sport science

Sport science includes the study op psychology, physiology, biomechanics, nutrition, sport technology and performance measurement. Various institutions provide testing facilities that are able to determine muscular functions. The analysis of different sport requirements can be used to determine the optimal dimensions and muscular strength ratios that will ensure maximal performance for a specific athlete participating in a specific sport discipline.

6.2 Peer review comments

The principles developed during this research were presented at an international sports science conference, the "2014 International Colloquium on Sport Science, Exercise, Engineering and Technology" (ICoSSEET 2014) held at the Bayview Beach Resort, Penang, Malaysia from the 7th to the 9th of April 2014. The topic of the paper presented was "Performance Comparison Across the Boundaries of Events, Gender and Age".

On the abstract this review was given by an unknown reviewer: "This paper introduces a novel procedure or model to generate performance tables allowing the comparison of track and field athletics performance across different events, gender, and age groups. The contribution of the paper fits in the theme of the symposium".

During the presentation, chaired by Joel Cressman (Taylor's University, Malaysia) and Zaifilla Farrina Zainuddin (Universiti Kuala Lumpur IPROM & University Teknologi MARA, Malaysia), all remarks received were that the approach and work was new and unique. This can be confirmed by the conference chair Rahmat Adnan using the EDAS identifier rahmatadnan@salam.uitm.edu.my. A number of private discussions were held after the presentation that had to be terminated by the chair after an extended period of 30 minutes on questions and answers.

The paper presented is published by Springer as “Proceedings of the International Colloquium on Sports Science, Exercise, Engineering and Technology 2014 (ICoSSEET 2014)”, available at http://www.springer.com.

A copy of the publication is also available as attachment “ICoSSEET2014 - FULL BOOK.pdf”. The paper presented is marked as paper 55 available starting on page 238 of the book.

In an e-mail message Attla Spiriev remarked: “You are the first to produce proof of the problems in the IAAF tables.” Copies of the original messages are in the attached CD.

6.3 Relevance to current problems

6.3.1 Assisting coaches and administrators

Coaches use training programs based on the performance targets set for athletes and quite often the services of a psychologist are used for mental preparation.

The problems facing athletes and coaches are to select an event or group of events in track athletics for multi-skilled athletes. Mostly the selecting for a specific meeting will be based on the preferences of the athlete and a knowledge of the competitors at the specific meeting.

Using the comparative tables it will be possible to select the best event(s) of the athlete based on actual performance measurements in the individual events.

Team managers will be able to select athletes and events for limited participation meetings that will ensure optimal team scores.

At primary school level a large number of possible future athletes are not identified because of a lack of comparative measurements. The skills development of younger athletes are quite often based on factors such as personal preferences of the coach and parents. This can be mostly attributed to the lack of comparative measuring tools and a program to identify potential.

6.3.2 Combined event competitions

The table scores obtained in the individual events can be added to produce the final scores for each athlete in the competition. These competitions include the pentathlon (5 events), heptathlon (7 events), octathlon (8 events) and decathlon (10 events).

At present the only available tables for measuring the results of these competitions are those published by the IAAF for senior athletes and these are the only tables used by the IAAF during meetings. On publication of results no mention is made of any table scores for normal track and field events.

The problem in the two tables used by the IAAF (one for normal track and field events and a second table for combined event competitions) arises from the maintenance of a “Record” based on the total scores. The variations in events and abilities of the athletes specializing in combined event competitions are the same as for any other athlete but to maintain a standard for record purposes tables cannot be the same.

The author suggests that a separate set of records is recorded for the events included in the various combined event competitions rather than the total scores as records, which is the current practice. This will then remove the need for a separate table and the performances of athletes can be compared to those participating in normal competitions.

The complication of adjusting the combined event tables to accommodate advancement in training, tracks and equipment, while also maintaining the total score record, will be removed.

As with current practice by the IAAF, it is not fair to compare the total score divided by the number of events to that of an individual score of an athlete in normal competitions. A multiplier (outside the scope of this research) can be determined for such comparison. This multiplier can then be used to replace the current tables published by the IAAF to convert combined event scores to comparative single event scores.

6.3.4 Extension to Masters Athletics

Athletes peak in the age group 22 to 35 years of age and thereafter there is a deterioration of performance. Athletes older than 30 years compete in a competition known as "Masters" athletics. These competitions are recognised worldwide with international competitions and a world championship every 4 years. Using the same principles, the tables can be expanded to include Masters Athletics.

The Masters competitions start at age 30 and they are grouped in 5 year intervals. Informal investigations show a possible trend to link masters competitions to that of schools by equating 30-34 years to 20 years, 35-39 years to 19 years, 40-44 years to 18 years and continuing with this up to the ages 90-94 year equal to 8 years. This is however currently just a consideration and ASWD (Athletics South Western Districts) based in George is currently testing the acceptance of these suggestions.

6.3.5 Modifications for handicapped athletes

It may be possible to use the available disability factors for the handicapped as a multiplier to achieve comparative scores. By including these factors in the formulation the scores will not reflect the finishing position in a race but the relative performances of the athletes.

6.3.6 Transferences to other types of sports

As human performance in any individual sport event is based on the same logarithmic principles, it may be possible to transfer the same principles to any other sport in which the result is based on the measurement of time or distance achieved by an athlete. Schools have asked the author for similar tables in swimming events.

6.3.7 Summary

The formulations in this dissertation are unique for track and field athletics and it was verified that the comparisons are valid across all events, age groups and also for gender differences. This was confirmed during peer reviews at an international sport conference.

The generated tables will assist coaches and administrators to develop training programs and team selections. During meetings these tables can be used to identify trophy winners in single and combined events.

A single set of tables can be used for normal track and field meetings and for combined event meetings.

The formulation can be transferred to any other sport where individual performances are used to determine the results of the sport.

In chapter 7 the final formulations will be summarized.

Chapter 7: Conclusions and future investigations

7.1 Acceptability of case study results

The original objective of finding a formula that will be able to correctly compare the performances of different events, age groups and gender was achieved. Using international and local data from a large number of meetings, from different venues and including a representative number of age groups from both genders, a consistent formula could be defined applicable to all tables.

Furthermore the research shows that consistent functions could be developed to establish standards for different ages (first sub-objective) from the data of a single age with reliable data. It was also established that it is possible to generate standards for different events within an age group (second sub-objective) using a hybrid polynomial function. Using fixed multipliers it is also possible to determine the standards for all track events with obstacles and all field events. The third sub-objective was also achieved by defining a function for the determination of standards for girls using the standards obtained for boys.

This implies that it is possible to generate all standards and comparative tables from the measured standard of a single event. In practice however, the freedom of variation is included to adjust the constants used in the functions. This is available if a new set of standards must be based on a number of measured values instead of a single value.

The base value(s) for a revision of the tables can be from any age or gender and if multiple base values are used, these can be from different events, ages and gender. In practice one or more weighted results will be used as confirmation of the generated standards and may also act as guidelines for minor adjustments which will be applied to all events.

The final function to generate all the tables (main objective) has the form:

$$Performance = a.b^{c.Point\_score}$$

The table will reflect performances on a scale from 0 to 1000. It is however not limited at the top mark and can be extended for individual performances exceeding the normally expected range for a specific event.

Additional to the primary objective a requirement was the acceptability of table values between events which require event standards. As more reliable data is available at national level the standards are set at the 5 year average of the 5^{th} position in all events in the highest meeting level. This will provide consistency in comparing other performances in different events. This average is defined as the standard performance and will be recalculated at periodic intervals to update the reliability of the tables.

For events not presented at championship level and to accommodate slightly offset averages, the averages will be used to determine the constants of a set of 2^{nd} order polynomial functions from which all standards are derived.

The same reasoning applies to field events where trending is used within a discipline. The relations between the weights of implements are used to determine the standards for related events.

This formulation was used to determine the constants of polynomial functions that will be used to set the relation between track events of different distances and for all events, the relation between performances at different ages within a specific event.

7.2 Function constants explained

As it is required to review the tables every four years it is important to collect reliable data during each season. Revised tables will be based on the data of the preceding five years. It is only required to use data in a single age group as the functions developed will be able to generate the standards for all age groups from the data in the selected group.

7.2.1 Weighted 5th position averages

The results in each event of the selected age group is sorted by performance and the lower performances of the same athlete is removed. An athlete will thus appear only once in a specific event but can also be included in another event. The same athlete can also be included in the same event in a different year.

The 5th position in each event is then used to calculate the standard of the event using the function:

Weighted average = (p1 + p2 + 2.p3 + 3.p4 + 3.p5)/10

Where *p(x)* = performance for year *x* and *x = 5* is the current year.
For track events the performance is converted to the standard speed by using:

Speed = Distance of the race/Performance to complete

7.2.2 Generating standards at 900 points

Using the speed values in the attached Excel spreadsheet (Table generator.xlsx), the constants for the function that will generate all track standards will be displayed. The data in the study period produced the functions:

General function: $y = a.x^2 + b.x + c$

Where a, b and c are constants depending on the range of the event and y is the 900 point standard for the range.

- 50m to 200m: $y = 0,0005.x^2 – 0,0164.x + 10,207$
- 200m to 800m: $y = 0,0489.x^2 – 0,7906.x + 10,848$
- 800m to 2000m: $y = 0,0016.x^2 – 0,1064.x + 7,8551$
- 2000m to 10000m: $y = 0,0064.x^2 – 0,1357.x + 6,8853$

These functions are continuous at the intercept points which implies that both functions will produce the same standard value. In these functions x is the race distance and y is the required 900 point standard of the race. The supplied Excel spreadsheet will generate all standards for the track events used by ASA in the senior men age group.

7.2.3 Extending the standards to other age groups

Expanding the tables to other age groups is obtained by using the 4th order polynomial:

$$y = 4.10^{-5}.x^4 – 0,0016.x^3 + 0,00934.x^2 - 0,06852.x + e$$

where y is the event standard and x = 26 – age group value and e is the event offset constant. In the Excel spreadsheet the value of e, for each event, is adjusted to reflect the correct 900 point standard. This is automatically calculated in the spreadsheet using the function:

$$e = y - 4.10^{-5}.x^4 + 0,0016.x^3 - 0,00934.x^2 + 0,06852.x$$

7.2.4 Extending the standards for hurdle events

In the determination of standards for senior men the corresponding track distance is used and multiplied by the value 0,8732 for 110 meter hurdle event and by 0,93073 for the 400 meter hurdle event. Extension of the standard for all other age groups are determined from the corresponding distance in the track using the functions:

$$\textit{Standard} = (\textit{Hurdle height (cm)}/106{,}7)^{0{,}4}.\textit{Distance multiplier}$$

for short hurdles and

$$\textit{Standard} = (\textit{Hurdle height (cm)}/91.4)^{0{,}1}.\textit{Distance multiplier}$$

for long hurdles.

The values 106,7 and 91,4 are the corresponding hurdle heights in centimetres for senior men.

7.2.5 Extending the standards for steeple chase, walk and relays

For all steeple chase events the multiplier 0,93082 is used for senior men and then the age adjustment in paragraph 7.2.2 is applied for any other age group.

A multiplier for race walking was obtained from the corresponding track event and using a multiplier of 0,6060. A different multiplier may be used by comparing the events for schools rather than that of seniors due to the lack in available data for senior men.

The relay standards are derived from the corresponding track distances and only for total distances shorter than 800 meter a multiplier is applied. For 4 x

100 meter or shorter the multiplier is 0,9638 and up to 4 x 200 meter a multiplier of 0,9824 is used.

7.2.6 Standards for field events

The 5 year averages are used for senior men and the same age extension formula is used to determine the constants for all age groups, where implements are used the multiplier

$$\textit{Weight multiplier} = (\textit{Weight of implement/Senior men implement weight})^{k}$$

is used where *k* will be adjusted during the revision to cover the range from maximum to minimum implement weights.

7.2.7 Standards for female athletes

All calculations (7.2.1 to 7.2.5) are repeated using the corresponding averages for female athletes. Al calculations are formulated in the table generating spreadsheet.

7.3 Generating the table scores

All tables are generated using the function:

$$y = a.b^{c.x}$$

where the integer value of *y* is the table score, x is the performance and *a*, *b* and *c* are constants.

The value of *c* is fixed for all events as 0,0006, The value of *b* will have two sets of values. For track events *b = 2,6* if the performace is above the standard performance and *b = 3,3* if the performance is below the standard. For field events *b = 15* if the performace is above the standard performance and *b = 3,3* if the performance is below the standard.

The value of *a* also has different values above and below the standard performance. The ratio between these values is *a2 = a1/1,17396* for track events and *a2 = a1/0,4415* where *a1* is the value above and *a2* the value below the standard performance.

The value of *a1* is calculated at the 900 point value using the function:

$a1 = 900/2{,}6^{0{,}0006.x}$ for track events and $a1 = 900/15^{0{,}0006.x}$ for field events where *x* is the standard performance.

7.4 Table generation

The simplest way to generate the final tables will be to use a Microsoft Excel® spreadsheet. All the functions in paragraph 7.2 and 7.3 are included in the spreadsheet. In future work this will be coded as a windows® application.

The "Table Generator.xlxs" annexure can be used to develop all or a subset of tables.

The procedure to develop the tables is as follows:

- Obtain the current year data from the meeting results
- Extract the 5th position performances for all events
- Enter these values on the spreadsheet as year 5 data. The existing data is moved back and the 1st year data is removed
- The weighted 5 year standards will be calculated automatically:
- The changed polynomial standards will be displayed

- Transfer these constants to the formula area
- All adjusted standards will be generated
- All tables will be generated using the derived table functions and constants

7.5 Non-standard events

Some schools are using events during house meetings or interschool meetings which are not in the list of standard events. Now that the method of obtaining standards and the function for the table generation is available, it is a simple exercise to generate tables for non-standard events.

Some of these standards can be directly derived from the current standards. For example some schools have a “winners relay” consisting of 4 athletes from different age groups each running a 100 meter leg. This standard can simply be determined by adding the four 100 meter standards and multiplying it by the relay constant for the 4x100 meter event.

Others need input from the school to provide their observed historical results to provide a suggested value that can be used as a standard. Then it is simply a selection of the type of event to use the corresponding generation formula for the table. Only information in one age will be required to generate tables for a range of ages using the age polynomial function. Current events in this category used by some schools include Turbo Javelin Throw and Cricket Ball Throw.

7.6 Publication of the tables

A decision made by ASA, to keep the cost of distribution low, is to publish the tables in printed format using a 10 point interval. This will be sufficient to do comparisons between performances in different events fairly accurately. Software programs used during a meeting will provide more accurate single point comparisons and will also be able to expand beyond the 1000 point mark for exceptional performances.

During training sessions the 10 point interval will provide sufficient information to coaches to monitor the improvement of athletes.

To increase readability and usefulness of the printed tables each age group and gender will be on separate pages. Only the standard events as published in the technical standards are included.

Using the 10 point interval only two A4 pages can be used for a specific age with page one the scores from 1000 points to 500 points and page two the continuation from 500 points to 0 points. A partial typical page is shown in Table 7.1.

Table 7.1: Typical table generated from standards

	Track senior men												
	100m		200m		400m		800 m	1500 m	3000 m	5000 m	10000 m		
1000	9.8	10.06		20.11	44.5	44.59	1:41.19	3:31.83	7:35.10	13:14.10	27:29.07	1000	
990		10.09	19.9	20.18	44.6	44.77	1:41.45	3:32.75	7:37.71	13:18.95	27:39.15	990	
980		10.13	20.0	20.26	44.8	44.96	1:41.71	3:33.69	7:40.38	13:23.92	27:49.46	980	
970	9.9	10.16	20.1	20.34	45.0	45.16	1:41.98	3:34.66	7:43.11	13:29.01	28:00.02	970	
960		10.20	20.2	20.42	45.2	45.35	1:42.25	3:35.64	7:45.90	13:34.21	28:10.83	960	
950		10.24	20.3	20.50	45.4	45.56	1:42.53	3:36.65	7:48.75	13:39.53	28:21.88	950	
940	10.0	10.27		20.59	45.6	45.76	1:42.81	3:37.68	7:51.67	13:44.97	28:33.18	940	
930		10.31	20.4	20.67	45.8	45.97	1:43.10	3:38.73	7:54.65	13:50.54	28:44.74	930	
920	10.1	10.35	20.5	20.76	46.1	46.19	1:43.40	3:39.79	7:57.70	13:56.23	28:56.56	920	
910		10.39	20.6	20.85	46.3	46.41	1:43.69	3:40.89	8:00.82	14:02.05	29:08.65	910	

900		**10.43**	**20.7**	**20.94**	**46.5**	**46.63**	**1:44.00**	**3:42.00**	**8:04.00**	**14:08.00**	**29:21.00**	**900**
890	**10.2**	**10.47**	**20.8**	**21.03**	**46.7**	**46.86**	**1:44.31**	**3:43.14**	**8:07.26**	**14:14.09**	**29:33.65**	**890**
880		**10.51**	**20.9**	**21.13**	**47.0**	**47.09**	**1:44.63**	**3:44.30**	**8:10.60**	**14:20.34**	**29:46.63**	**880**
870	**10.3**	**10.56**	**21.0**	**21.22**	**47.2**	**47.33**	**1:44.95**	**3:45.50**	**8:14.02**	**14:26.75**	**29:59.94**	**870**
860		**10.60**	**21.1**	**21.32**	**47.4**	**47.57**	**1:45.28**	**3:46.71**	**8:17.53**	**14:33.32**	**30:13.58**	**860**
850	**10.4**	**10.65**	**21.2**	**21.42**	**47.7**	**47.82**	**1:45.62**	**3:47.96**	**8:21.13**	**14:40.06**	**30:27.57**	**850**
840		**10.69**	**21.3**	**21.53**	**47.9**	**48.08**	**1:45.97**	**3:49.24**	**8:24.82**	**14:46.96**	**30:41.91**	**840**
830	**10.5**	**10.74**	**21.4**	**21.63**	**48.2**	**48.34**	**1:46.32**	**3:50.54**	**8:28.59**	**14:54.04**	**30:56.60**	**830**
820		**10.79**	**21.5**	**21.74**	**48.5**	**48.61**	**1:46.68**	**3:51.88**	**8:32.46**	**15:01.29**	**31:11.66**	**820**
810		**10.83**	**21.6**	**21.85**	**48.7**	**48.88**	**1:47.04**	**3:53.24**	**8:36.42**	**15:08.72**	**31:27.09**	**810**
800	**10.6**	**10.88**	**21.7**	**21.96**	**49.0**	**49.16**	**1:47.42**	**3:54.64**	**8:40.47**	**15:16.33**	**31:42.89**	**800**

For events up to 400 meter both the hand and electronic performances are shown as a large number of meetings use hand timing. Using this format will limit the number of pages for any age group to 2 pages, compared to 20 pages if single point intervals are used.

7.7 Confirming the research objectives

7.7.1 First sub-objective – Setting standards from reliable data

This objective forms the base of all the other functions and will eventually determine the acceptability of the table results in all events. To ensure a reliable starting point it was decided to use the 5th position of all reliable performances in a specific year in all events. Reliability of a result is defined as a result obtained during a meeting approved by ASA, all the officials responsible for measuring the performance are qualified in the specific event and all implements used have passed the assize requirements. All time measurements were done electronically and wind readings were obtained for events requiring these readings.

7.7.2 Second sub-objective – Expanding the standards to other age groups

In the case of track events (excluding events with obstacles) the standard values are used to determine the best fit constants for the four groups of 2nd order polynomials. This method ensures that singe event exceptions are corrected and standards can be generated for the events not available in the age group used to establish the base standards.

For hurdles the standard is determined from the corresponding distance in the track multiplied by a hurdle height ratio.

Similar multipliers are derived for steeple chase, race walking and relay events.

The calculation of the standards for field events is similar to those of hurdles but the lack of reliable data requires the calculation of deviation adjustments. This calculation is done automatically in the table generation spreadsheet and can be seen on the "Throw Standards" sheet.

7.7.3 Third sub-objective – Expanding the standards to female events

It was determined that in all events female athletes' performances follow the same reasoning as for male athletes with lower standards and a more pronounced deterioration as the performance position decreases. It is thus possible to use exactly the same functions for all events as those for male events to determine the standards. Because the tables use a progressive function, the change in standards will then automatically adjust the table performances to produce correspondingly more pronounced adjustments in performance changes.

7.8 Primary objective – Generating tables for performance comparison

It was determined that a single function, $y = a.b^{c.x}$ can be used for all events. To adjust the spread of data different values of *b* are used for performances above and below the standard performances. The actual values used and the confirmation of the validity of these values were completely explained in chapter 4.6.

Using the hybrid model *a* and *b* have different values for performances above and below the standard performances.

Using these values will ensure the following:

- 0 point performance is about ½ of the standard
- Records are at about 1000 points
- The function is continuous through the 900 point value

7.9 Combined formulation steps

To obtain updated tables it will only be required to update the weighted averages for senior men and follow the instructions in the table generating steps in the spreadsheet.

These instructions are given on three sheets of this spreadsheet.

Track standards sheet

Instructions	
Step 1	Move the year data 1 column back. (Drop the oldest data.)
Step 2	Add the current year 5th position data.
Step 3	Transfer the polynomial constants from the graphs to the table
	All standards will be generated.

Jump standards sheet

Instructions	
Step 1	Enter the 5 year average values in the top table.
	For unknown values, use a good approximation.
Step 2	Write the a, b and c values displayed on the graphs in the above table.
step 3	Adjust the c values to match a desired value in the bottom table with the top table.
step 4	Adjust the b value to get the deviation to 0. Not more than 5 decimals.
step 5	If deviation is not 0, adjust a up to 9 decimals to obtain 0. (4 decimal accuracy). If match-up 3 is changed, repeat steps 3, 4 and 5.

Throw standards sheet

Instructions	
Step 1	Enter the event 5 year averages in the **standards** column. Use the correct 5 year average
	for each age group. If not available use a good projected value.
Step 2	Adjust the **Base** value until the value in blue (25) match the 25 year standard.
	If the 25 year standard is questionable, do this for a match in the blue 19 standard.
Step 3	Adjust the **Multiplier** until the lowest age (or any other reliable age), the **Blue** value
	match the standard value for that age. (Step 2 can be repeated.)
step 4	Adjust the "**a**" value until the average deviation is 1.
	If not possible (all bigger than 1 or all less than 1) use a different age in steps 2 and 3.

On completion of these steps all the tables will be available on the table sheets.

7.10 Future development

Mostly schools require an automated system that will produce the inverse function of the table generation. Instead of obtaining the table score for a specific performance from a printed table, it is required to produce the point from a performance input using software. This can then be used during track and field meetings. The software must not only be able to generate the table scores but it must be able to perform all the functions required before, during and after a meeting. This will include team registrations, event selections for team members automating the input of results from electronic timing and event spreadsheets, generation of different reports, team selection from the results of a meeting based on various criteria, and much more.

With the available technology it can be possible to have a service where a school could have a paperless meeting. This can be achieved by using tools such as tablets and smart phones capable of running compatible software for spreadsheet handling and internet connection. The officials complete predefined spreadsheets at the point where the event is taking place as the meeting progresses. The completed documents can be placed on the cloud (SkyDrive, Dropbox, etc.) and then captured at a central point from where the event and meeting results can be captured and published.

Using the same principles it is thus also possible to have a “distributed” meeting between teams competing at different venues. Obviously it will be a requirement that similar environments (track surface, etc.) must be used.

The next stage will then be to develop the administrative software for the various platforms to integrate the tables with meeting results.

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