Weight and the Marathon des Sables

Issues of Weight

Aspects of weight related to multi-day, ultra-endurance races like the Marathon des Sable, Kalahari Augrabies Extreme Marathon and other multi-day events.

October 2014

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Reference:

The content of this paper may be referenced as follows:

Pieterse, G. 2014. Aspects of weight related to multi-day, ultra-endurance races like the Marathon des Sable, Kalahari Augrabies Extreme Marathon and other multi-day events. Published by push2extreme.com.

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INTRODUCTION

During 2013 I participated in the Marathon des Sables (MdS) and decided to conduct research on the elements that drives race performance, not only for the top runners, but across the entire spectrum of participants. It was clear from the outset, that there were two distinct groups of runners which participate in multi-stage or multi-day ultra-endurance, self-supported races. The first group are there to compete, and have the natural or genetic ability to function at a competitive level. Although they have genetics on their side, to effectively compete, they need to bring together, training, nutrition, strategy, and a host of other elements, without which not even the best genetics can secure a place in the top 10 or 5 percent. The second group are not there to compete, but are there for the challenge. This group has varied genetic ability, varied running experience and represents the bulk of runners to be found in multi-stage, multi-day, ultra-endurance events.

The original aim of the research was to determine how the various elements work together to determine runner specific performance before and during the race. The processed data has been published[1] as has individual discussions of specific aspects of the research[2] [3].

In this discussion report, I am specifically focusing on aspects related to weight, and in particular those elements that have not yet been fully explored in previous discussions. As the research progressed it became evident that the multi-day self-sufficiency ultra-endurance runner has to bring together three critical elements related of weight to ensure performance during the event. The three critical elements are:

- Runner Weight,
- Runner Body Fat Percentage, and
- Runner Race Pack Weight.

The research clearly indicates that there is a disconnect between the pre-race race-pack weight anticipated by many of the runners versus the actual race-pack weight. This under-estimation of

[1] https://www.scribd.com/doc/151364801/Marathon-Des-Sables-Survey-Data
[2] http://www.push2extreme.com/#!blog-page/c1bc9
[3] http://theroadtomds.blogspot.com/

race weight, leads to undertraining in-terms of race-pack weight, which, obviously results in some level of impaired performance. For the first-time an extensive empirical study of the relationship between body weight, and body fat, in-terms of self-sufficiency multi-day ultra-endurance performance has been done. Previous studies were based on shorter distance, single day events which differ substantially from the conditions experienced by a Marathon des Sables (MdS), Kalahari Augrabies Extreme Marathon (KAEM), or any of the other similar races multi-day event, runner.

The format of this discussion will consider, firstly, runners weight in terms of race performance, then a discussion will follow on the body-fat percentage of a runner and how that translates into performance and thirdly consideration will be given to realistic race-pack weight. Finally various approaches to race target pace / speed will be discussed to provide a realistic race target setting mechanism within the context of weight.

BMI vs RACE PERFORMANCE

In recent months, and in preparation for the 2015 Marathon des Sables, I have seen various challenges related to individual weight loss. The primary rational used in the weight loss drive, is that a lighter body weight will translate into some form of runner benefit. In principle there is nothing wrong with this hypothesis, I did, however, return to the 2013 research data in an attempt to (a) test the hypothesis against the empirical data, and (b) to find the boundaries beyond which a specific BMI level no longer translates into some form of runner performance benefit. It must be noted that I do not challenge the well supported premise that a low fat body composition has health benefits, this discussion, however, focuses on the possible benefits from an ultra-endurance, multi-stage, multi-day, self-support race perspective, and aims to find the point at which personal body weight reduction loses its benefit.

BMI DEFINED

BMI or the Body Mass Index is a universally used calculation, that is aimed at relating an individual’s weight in relation to a global statistical norm of other individuals of the same height. The result is used to class individuals as normal, over or under weight. My own view is that this is a fairly realist view of the masses, but often lacks individual context. It would be far better to view BMI in conjunction with measured body fat percentage, as a highly muscular individual could translate into a higher body weight for his or her length. There are a number of misleading articles on fat and muscle which claim that there is no difference, however, the truth is that a cubic centimetre of muscle does weigh more than a cubic centimetre of fat. It is reported that fat has a density of 0.918g/cc and that muscle has a density of 1.049g/cc[4], this represents a difference of around 14%, which is significant when viewed in-terms of BMI. My use of the BMI calculation is not as a determining factor of normal, over or under weight per say, but is used as a fixed point against which a well-defined norm is established across the entire data population, in an attempt to relate comparable individual body weight to performance. Therefore, when I use the term over weight, or normal weight, it is not a validation of the BMI classification but merely a consistent use of the term. What is important for this discussion, however, is the relationship between BMI and race performance.

BMI CALCULATION FORMULA

The standard formula used in calculating an individual's BMI is the following:

$$\boldsymbol{BMI} = \frac{\boldsymbol{Mass}\ (\boldsymbol{kg})}{(\boldsymbol{Height}\ (\boldsymbol{m}))^{\mathbf{2}}}$$

This means that an individual who weight 80kg's and has a height of 1.78m will have a BMI of 25.25. This calculation can also be done in reverse. If you have a target BMI you could determine your specific weight by using the formula as follows:

$$\boldsymbol{Mass}\ (\boldsymbol{kg}) = \boldsymbol{BMI}\ \times \boldsymbol{Height}\ (\boldsymbol{m})^{\mathbf{2}}$$

[4] Johnson, C. 2014. Accurate and Easy Body Fat Determination. Johnson is a theoretical physicist with a physics degree from the University of Chicago and publishes his research online at http://mb-soft.com/public2/bodyfat.html

BMI RANGES

The accepted BMI ranges include the following:

Category	BMI Range (kg/m²)
Underweight	16.0 to 18.5
Normal Weight	18.5 to 25.0
Overweight	25.0 to 30.0

Table 1: BMI Range

The Centres for Disease Control and Prevention (CDC) in Atlanta, Georgia has a brief but informative article on their website[5], which highlights the fact that BMI is influenced by gender, age, ethnicity etc. It is worthwhile taking the time to become familiarised with the concept of BMI, the variances, and the elements that might impact directly or indirectly upon an individual's BMI.

PERFORMANCE DATA

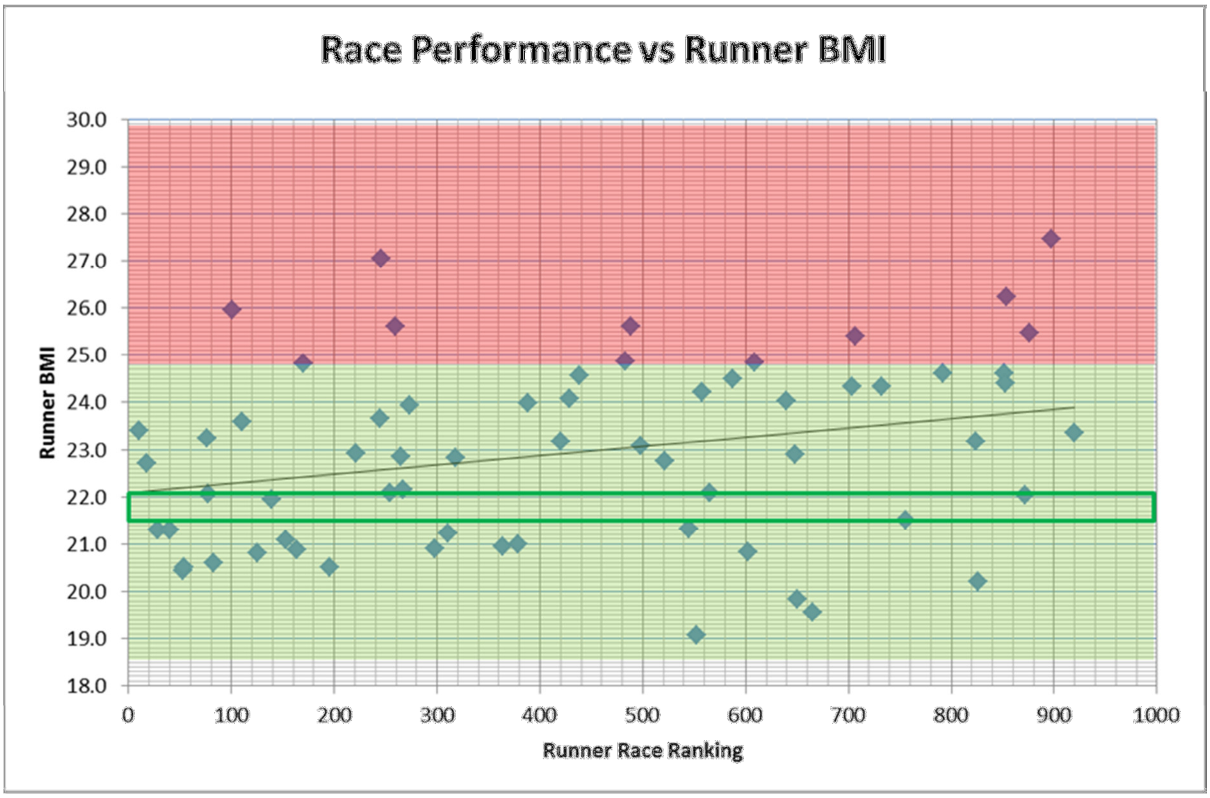
In review of the research data a number of elements were important to determine, these were the following: (1) The distribution of runner BMI in relation to overall race ranking (which was interpreted as an indication of race performance), (2) the performance level of runners with an overweight BMI. A further analysis was done to determine the performance level of (3) runners with a BMI in the centre of the normal BMI range, (4) for runners below the centre of the normal BMI range, and for (5) runners that had a BMI higher than the centre of the normal BMI range. In the data set no runners had a BMI below the normal range.

Distribution of Runner BMI in Relation to Overall Race Ranking

In the 2013 Marathon des Sables data population, 84.6% of the runners had a normal BMI and 15.4% had an overweight BMI. Graph 1 below, represents a scattered view of BMI levels in relation to overall race ranking. The area that is shaded red represents that cluster of runners with an overweight BMI, while the green shaded area represents the cluster of runners with a

[5] http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html?s_cid=tw_ob064

normal BMI. The green bloc demarcation that spans from 21.5 to 22.0 on the BMI range represents the centre of the normal BMI range.



Graph 1: Race Performance vs. Runner BMI

As can be seen, an overweight BMI does not automatically equate to a reduced performance as there are a number of runners with an overweight BMI that finished in the top 300. The opposite is also true, that a normal BMI is no guarantee for a high ranking as a number of runners ended in the last 300.

Performance Level of Runners with an Overweight BMI (24.9 plus)

Runners with an overweight BMI (24.9 plus) represents 15.4% of the total data population. Of this group 27.3% could not complete the Marathon des Sables, 36.4% finished in the last 300, 27.3% in the top 300 and the remaining 9% finished in the middle 400. The risk of not completing the race is significant among this group; based upon this, any weight loss aimed at reaching a normal BMI has material value for the individual. However, weight loss, seems to have a benefit to the runner anywhere within the normal BMI.

Performance Level of Runners with a BMI in the Centre of Normal BMI Range (21.5 to 22.0)

Only 4.6% of all finishers had a BMI in the centre of the normal BMI range (between 21.5 and 22.0). Of this group 33.3% ended in the top 300 while the remaining 66.7% all finished in the last 300. This centre line seems to form some dividing line with the majority of finishers falling above or below the centre of the normal BMI range.

Performance Level of Runners below the Centre of the Normal BMI Range (18.5 to 21.5)

29.2% of all finishers had a BMI below the normal mean. Within this group 52.6% finished in the top 300, 42.1% finished in the middle 400 and 5.3% finished in the last 300.

Performance Level of Runners that had a BMI Higher than the Centre of the Normal BMI Range (22.0 to 24.9)

This is by far the largest group within the data population, representing 50.8% of all finishers. This group saw 36.4% finish in the top 300, 21.5% in the middle 400 and 10.8% in the last 300.

BMI CONCLUSION

Evidently, the case for some level of weight loss is well founded as there seems to be a link between a normal BMI and ranking. It is important to note that BMI alone is not a predictor of performance but merely one element that plays its part in a runner's overall performance. Natural ability, age, race conditions, mental conditioning, training and psychological state, among others, in combination, plays a decisive role in a runner's performance. The BMI data and conclusion should be interpreted within the context of this statement.

It is clear, that a runner with the ability to compete for a top 700 placement should target a BMI somewhere between 18.5 and 21.5 as both the top 300 and middle 400 runners both seem to benefit from this BMI range. It is, furthermore, worthwhile noting that the highest placed 'overweight' male featured within the top 100, with a BMI of 26.0, while, a runner in the top 10 had a BMI of 23.4. Both of these fell well beyond the 18.5 to 21.5 BMI range. It is my view that some level of weight loss is beneficial, and that the aim should be to, at least, reach a normal BMI level. However, other factors such as pack weight, will play a significant role in exactly what body weight target should be set.

BODY MASS to BODY FAT PERCENTAGE

Weight loss is often considered from a body fat percentage perspective with a body fat percentage target set as the goal. This should, as the body weight loss target, be set very carefully. Using the formula presented by Deurenberg, *et al*,[6] in their 1991 research.

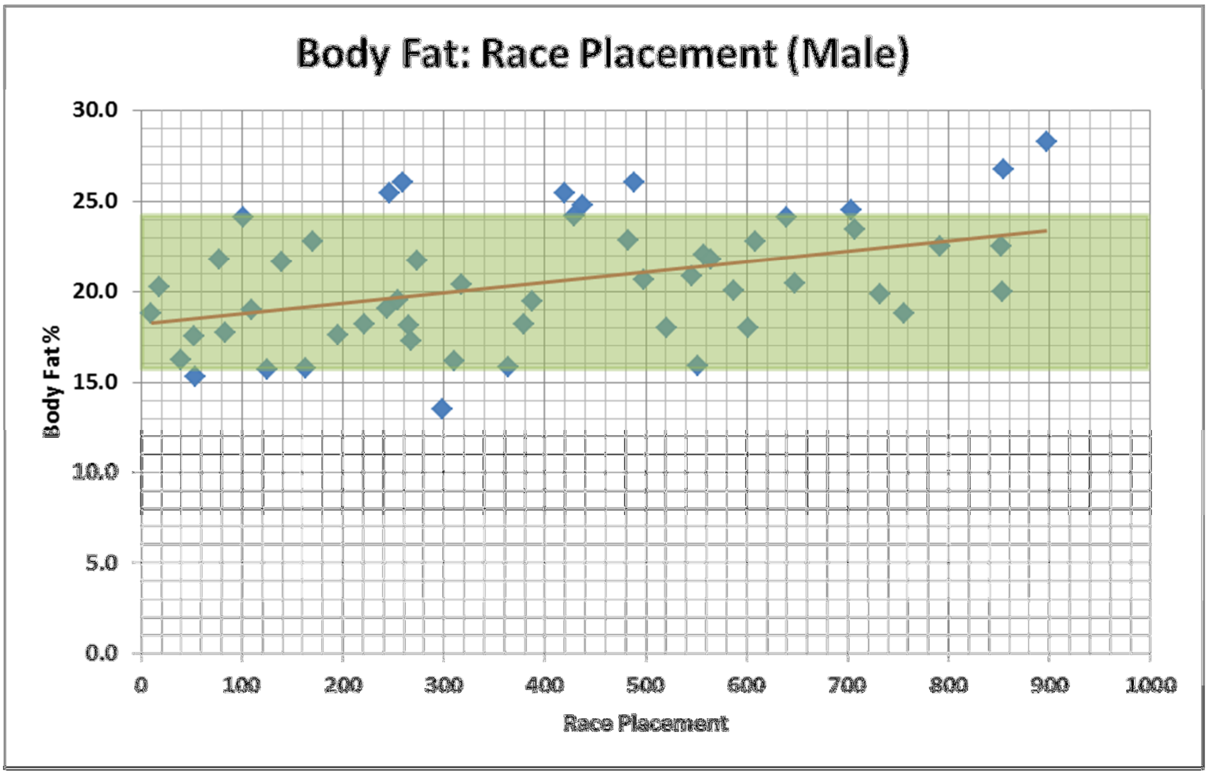
$$\boldsymbol{Body\ Fat}\ \% = (\mathbf{1.20} \times \boldsymbol{BMI}) + (\mathbf{0.23} \times \boldsymbol{age}) - (\mathbf{10.8} \times \boldsymbol{gender}) - (\mathbf{5.4})$$

Where the gender factor is 1 for male and 0 for female.

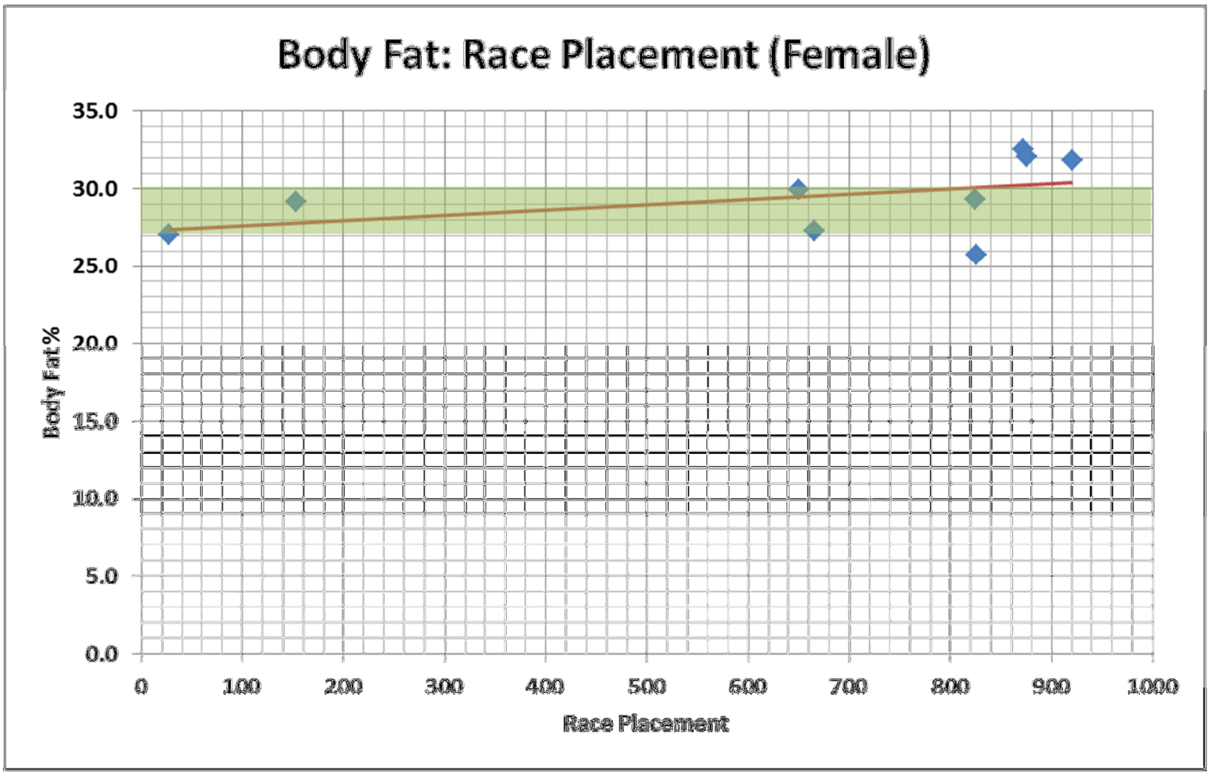
As can be seen from the performance data plotted in Graph 2 below, 80% of the MdS 2013 male runners had a calculated body fat percentage of between 16% and 24% (20% ±4%). The top 40 male runners had a strong concentration of body fat percentage of 17.5% to 19.5% (18.5% ±1%), while a male body fat percentage above 26% seems to be limited to the 100 slowest runners. Male runners with a body fat percentage below 14% also didn't make it into the top 100.

The plotted data of Graph 3 shows body fat percentage in-terms of performance for female runners. For this group, the performance seems to be much more constant for those runners with a body fat percentage that varies between 27% and 30% (28.5% ±1.5%). In this female group, a body fat percentage below 27% or above 30% seems to be limited to those runners finishing in the last 200.

[6] Deurenberg P, Weststrate JA, Seidell JC. 1991. Body mass index as a measure of body fatness: age- and sex-specific prediction formulas. British Journal of Nutrition, March 1991, Volume 65, Issue 2, pages 105-114.



Graph 2: Male Body Fat Percentage and Race Performance



Graph 3: Female Body Fat Percentage and Race Performance

It is commonly believed that a low body fat percentage equates to an improvement in performance, however, how low is somewhat more difficult to find consensus on, especially in the light of lacking extensive research on this important subject within the context of the self-sufficiency multi-day ultra-endurance races. It is commonly accepted that 'normal' body fat stores should range between 15% and 18% for males and 25% to 30% for women; however, what is 'normal' for a sprinter might not represent 'normal' for an ultra-distance athlete, so such a generalization is somewhat flawed. Fat stores are vitally important as they play a key role in tissue structures, hormone metabolism, impact protection (such as under the heel) and generally as a source of energy. For the ultra-distance runner, and specifically for the multi-stage / multi-day self-sufficiency runner who lives on an energy deficient diet for 7-days, while having to perform in an extreme environment, the energy function of fat reserves should not be under estimated.

Before we continue with the discussion on what constitutes the correct level of body-fat for the multi-day, ultra-endurance, self-sufficiency runner, it is important to consider what energy an 80kg male runner and a 60kg female runner will require for an event like the Marathon des Sable. The simplest approach would be to calculate energy requirement in-terms of an energy requirement of 1kCal per kilogram body mass per kilometre. This means that the male runner will require 20,000kCal's (250km x 80kg) and the female runner 15,000kCal's (250km x 60kg). Both these runners will require more calories than what the race rules suggest as a minimum, for the male runner, a deficiency of 6,000kCal's and for the female runner a deficiency of 1,000kCals. This suggests that the male runner should have an accessible fat reserve of 667grams, while the female runner will need to have access to 111grams of fat reserves. This is, however, an over simplification of the requirement as it excludes the energy cost associated with the additional race-pack weight, the increase energy consumed by the body for cooling etc. An 8kg race-pack will require an additional 2,000kCal's of energy over the duration of the event, whereas, the heart rate increase due to a high-level of activity or the heat would result in additional calories being required. The effect of heat should not be underestimated. Kristine Barry, states that the effect of heat on heart rate at between 16 and 24 degree Celsius will result in an increase of 2 to 4 beats per minute (bpm). At between 24 and 32 degree Celsius heart rate will increase by as much as 10 bpm[7]. Table 2 below, provides an indication of the effect of heart rate on energy consumption.

[7] Barry, K. 2011. Training in the Heat. Running Times, 19 July 2011. Runners World.

	Male 40 Years Old	Female 40 Years Old
Weight	80 kg	60 kg
Average Heart Rate (120bpm) ±67% of HR Max	639kCal's Per Hour	411kCal's Per Hour
Average Heart Rate (130bpm) ±72% of HR Max	730kCal's Per Hour	475kCal's Per Hour
Average Heart Rate (140bpm) ±78% of HR Max	820kCal's Per Hour	539kCal's Per Hour
Average Heart Rate (150bpm) ±83% of HR Max	911kCal's Per Hour	603kCal's Per Hour
Average Heart Rate (160bpm) ±89% of HR Max	1,001kCal's Per Hour	667kCal's Per Hour

Table 2: Relationship between Heart Rate and Energy Consumption

As can be seen from Table 3, if a 40 year old female athlete who weighs 60kg's, normally runs with an average heart rate of 140bpm, then during an event where the temperature reaches 30 degree Celsius, that same athlete will have a heart rate of 150bpm. The energy effect of this equates to 64kCal/h. If this female athlete runs at 5km/h, during an event like the MdS, the additional energy requirement due to heat results in 3,200kCal's over and above that which would normally be required. Consider that many of these types of races takes place in deserts with average daytime temperatures well in excess of 35 degree Celsius, and the effect is even greater.

It is extremely difficult, if not near impossible, to predict all variances and as such it is impossible to develop an all-encompassing energy requirement model. As such, the majority of runners will inevitably, arrive with a compliment of food that is calorific deficient. Previously, I published an article on nutrition in which stated an optimal calorie level taken by male and female runners to the MdS. The calorie level for males came to 0.91kCal/kg/km (0.91 ±0.18kCal/kg/km) and 0.78kCal/kg/km (0.78 ±0.17kCal/kg/km) for females. It must be noted that this optimal range was statistically determined in terms of runners with an average body fat percentage of 16% and 24% (20% ±4%) for male runners and 27% and 30% (28.5% ±1.5%) for female runners. In both cases athletes had available energy reserves, in the form of body fat, with which to supplement any calorific deficiency. Within this calorific and body fat percentage range, there seems to be a balance where performance is not undermined. If an athlete had to reduce his or her body fat percentage to the minimum healthy level (which is 5% for males and 10% to 15% for females), all calories will have to be carried as race food. The weight cost of packed nutrition (food taken to the race) versus fat reserves (body fat) on an optimal nutrition composition of 55% carbs, 20% protein and 25% fat, means that, packed food would come in at 4.375kCal's per gram (packaging included) while stored fat comes in at 9kCal's per gram. From this, it can be concluded that stored fat presents a far more optimal source of energy. A shortfall of 1,000kCals in terms of body fat equates to 111grams whereas packed race food will add an additional 229grams.

Returning now, to the initial discussion on body fat, from the MdS 2013 data above there is clear evidence that excessive body fat in both male and female runners, as well as, an 'over lean' or 'deficient' body fat in both male and female runners undermines race performance. In my discussion on how a calorific deficient diet can be supplemented by body fat, I was not implying that excessive body fat is an optimal approach, nor that good nutrition should be exchanged for an intentional calorific starvation, when running an event like the MdS. The aim is to find the balance between calories packed and body fat percentage, as a race management tool with which to sustain stable performance, where an athlete inevitably runs on a calorific deficient diet.

From the data it seems as if the optimal male range varies between 16% and 24% with the high performance range falling between 17.5% and 19.5%. In both observed cases, the top-end of the body fat percentage range is between 1.5% and 6% higher than the commonly accepted top-end range for male runners. On the opposite side of the spectrum, the commonly accepted minimum range of 15% is also not observed in the MdS data with 2013 MdS male participants, on average, measuring between 1% and 2.5%. But what does this mean in real terms? If a 70kg runner has a body fat percentage that is 2.5% lower than the observed data, the weight 'deficiency' this runner has is ±175grams. On the opposite side, the difference between the commonly accepted 18% and observed 24% for a 70kg runner is as much as 4.2kg. So a male runner preparing for a multi stage / multi day self-sufficiency race that adheres to the commonly accepted range could be as much as 4.2kg underweight from a sustained race performance perspective.

The commonly accepted 25% to 30% optimal body fat percentage seems to cover, at least towards the top end, the observed data among the MdS 2013 female runners. Again, however, the commonly accepted lower-end of the range (25%) is as much as 2% below the observed performance data (27%). For a 60kg female runner this could mean that the runner is as much as 1.2kg 'underweight' in terms of race performance.

Besides the minimum performance level, there is also a minimum health level, for men this seems to be around 5% of body fat, while for females, it is between 10% and 15%[8]. Dropping below this level results in an impaired immune system and can, on its own, impair the runners training schedule either through sickness, or injury. Female runners have to be particularly cautious, as dropping below the minimum level (12.5% ±2.5%) has been shown to result in bone mass loss which leads to, among other things, fractures in later life[9]. Obviously excessive body fat is equally detrimental to the healthy athlete.

If we assume, that the runner will have to extract as much as 50%[10] of their MdS race calories from their fat reserves, that the body will require around 1 kCal per kilogram body mass per kilometre and that there are 9 kCal's per gram of fat, then we can calculate the minimum fat reserves a runner should have to sustain performance. A 60kg female runner should, for sustaining health, have a body fat percentage of no less than 10%, or body fat of 6kg's. If that runner will extract energy from fat reserves for a multi-day event, such as the MdS, then the energy extraction from fat would calculate to 15,000 kCal's (Weight x Distance x 1kCal/kg/km).

[8] Journal of Sports Science 2004; 22:115-125
[9] Journal of Sports Science 2004; 22;1-14
[10] It is assumed that half of the total energy cost of a long run will come from fat; this is a somewhat general assumption as it will depend on the runner's speed, fitness, diet and many other factors. At a relatively low running speed, the total energy demand is low, with the majority of energy requirement being met through the oxidation of fat. Muscle stores, such as carbohydrate form muscle glycogen and blood glucose becomes the secondary energy source. For very fast runners, this is not the case, and the body will require energy at a much faster rate which places a primary demand on muscle and blood stores.

At 50% this would translate to a fat requirement of 0.83kg ((15,000 kCals/9)*50/100). Therefore, a 60kg female runner, setting out to run the MdS an absolute minimum body fat percentage should be 11.4%. It must be stressed that this is the absolute minimum. As a matter of fact the range for a 60kg female runner should be somewhere between 11.4% and 16.4% (13.9% ±2,5%). From this it is evident that an excessively lean body will not only impair performance, but could result in undermining the athlete's general health. The same can be calculated for male runners using the process described above.

There is a caution, however, when using this calculation to set a body fat percentage target. As speed increases, the energy obtained from fat decreases and the body extracts its energy primarily from muscle glycogen. This means that running slowly burns more fat, and less glycogen, slower runners, therefore, need a higher body fat percentage to perform during a multi-stage / multi-day race than the fast runners who would simply extract the required energy from their muscle and blood stores.

The problem with most body fat percentage race performance studies done to date, is that it is typically measured over shorter distances, such as 2 to 4km's. There is, therefore, some assumptions made as to the transferability of the short distance data to ultra-distance events, and experienced ultra-athletes will attest to the fact that there is a measurable difference in how the human body responds to 2km, 5km, 10km, 20km, 40km, 50km, 100km etc. and this is even more so when we come to muti-day, ultra-distance self-sufficiency events. For instance, the 1986, 2-mile body-fat race performance data study[11], concluded that leaner runners perform better overall, however, no real context was given to distances in excess of 2-miles, nor was the meaning of 'lean' adequately defined for the various distance runners. Professor Ron Maughan, from the Sport and Exercise Science Faculty at Loughborough University makes the following statement: "Although there's an intimate link between body fat levels and running performance, it's important to remember that reducing fat levels will not automatically guarantee success and may even be counter-productive. If you reduce fat by a combination of training and restricting diet, you are walking a fine tightrope. While a reduction in body fat may well boost running

[11] Journal of Sports Medicine 1986; 26:258-262

performance, cut down food intake too drastically and not only will training quality suffer, but the risk of illness and injury also increases dramatically”[12].

BODY FAT PERCENTAGE CONCLUSION

MdS 2013 performance data, for both males and female runners, set body fat percentage well above the minimum lean level of 5% for males and 12.5% ±2.5% for females. As a matter of fact, male performance seems to reach an ultimate breakdown point once body fat percentage goes below 14% or above 26%. For females, performance breakdown occurs when body fat falls below 27% or rises above 30%. The optimal body fat percentage, for a sustained performance level among 2013 MdS males are around 20% ±4%, with 18.5% ±1.5% representing the peak performance level. For females, optimal body fat percentage is around 28.5% ±1.5%.

I returned to the research data and considered the body fat percentage of the top twenty MdS 2013 male runners, excluding all other runners from the test. This was done to assess whether the optimal level, is indeed applicable, or whether the mass of other runners ‘contaminated’ the performance date due to overwhelming size. Looking at the top 20 runners only, refocused the performance data to the top 2% of the field. Among this group body fat percentage comes to 19.6% ±0.7%. The same was done for the top 20 female runners whose optimal body fat percentage came to 28.6% ±1.5%.

RACE PACK WEIGHT

Race pack weight is another weight related factor that has a determining effect on a runner’s performance. It goes without saying that the lighter a person’s race pack is, the less stress the runners body will experience, resulting in an improved performance. The question, however, is what is realistic, what can be achieved in terms of race pack weight while maintaining performance, and how would this translate to BMI. Race pack weight, is also not just a matter of packing light. There are very specific race rules to adhere too, while a runner’s size will determine his or her nutrition requirement.

[12] http://www.pponline.co.uk/encyc/running-and-body-fat-walking-the-tightrope-of-optimum-performance-32193#

Marathon des Sables race rules (Article 24) clearly state that a runner must start the race with a minimum 6.5kg (dry) race pack.

> *All of the obligatory equipment and personal belongings for each competitor (food, survival equipment and Marathon kit, waist pouch...) should weigh between 6.5kg and 15 kg. This minimum/maximum weight does not include your daily water supply.*

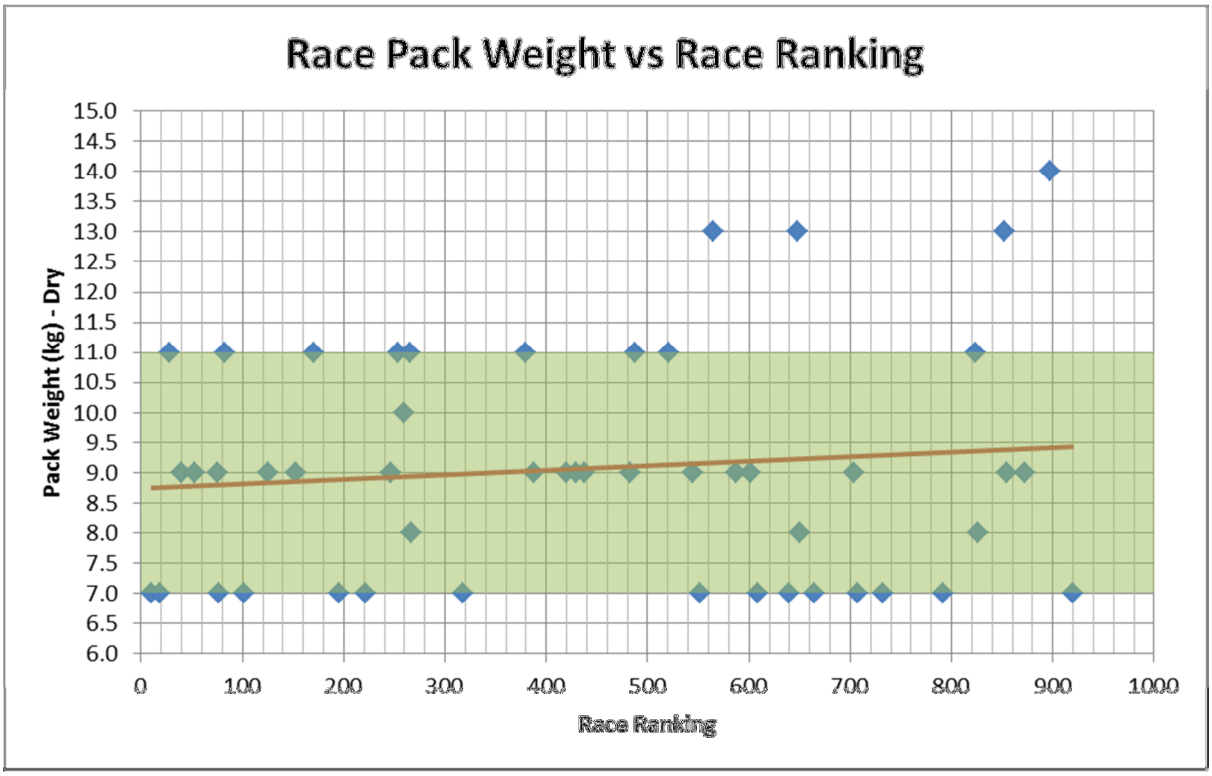
Added to this, the 1.5 litres of water that a runner must start with; then the absolute minimum allowable weight is 8kg's. The smaller and lighter a runner is the higher the impact of this weight will be on the individual. It is somewhat contrary to the idea of losing weight. However, there is a fine balance between the runner's body weight and his or her pack weight and an optimal range does exist.

It is worthwhile noting that race pack weight consists of three different weight components; the first being the fixed weight of all the items that will remain constant throughout the race. This means that a runner will end with the same items, weighing the same, as when the runner started the race. Examples of this would be the pack itself, clothing, sleeping bag etc. The second are those elements that gradually decrease over time, essentially this comprises of race food which is gradually depleted at a relatively constant rate. The third element is a 1.5kg oscillating element that is the water dispensed to the runners. When a runner leaves a check-point he or she will do so with a full complement of water weighing 1.5kg's, this will be depleted at roughly 150grams every kilometre.

A runner has ultimate control over the weight of the first element. Personal decisions of comfort, a runner's budget and practical considerations of safety and risk will ultimately drive the first element. The second element can be managed with a certain amount of movement, but there, ultimately, is an absolute minimum below which a runner can't take the weight of his food without (a) breaking the race rules, or (b) endangering his or her own life. The third element is one over which the runner has close to no control, and 'creative' approaches such as drinking half at the CP and running out of the CP with only half a water compliment to reduce weight, has seen many runners endangering their race by becoming dehydrated. Dehydration has a detrimental effect on a runner's race performance and as such, the possible weight gain such a drinking strategy may potentially have, is outweighed by the actual risk.

RELATIONSHIP BETWEEN RACE PACK WEIGHT AND RACE RANKING

The data collected prior and during the 2013 Marathon des Sables provides some idea of what a realistic minimum dry race pack weight is among the runners. The data over rides the theoretical notion of the ultra-light packs, and brings to light some realism. As can be seen from the accompanying graph (Graph 4) below, the performance across all race position placements seems to be fairly stable for dry race pack weights between 7 and 11kg's. This translates to a start weight of between 8,5kg and 12,5kg. The data shows that once the dry race pack weight nears the 13kg mark, performance breaks-down with no runners ranking higher than position 550.



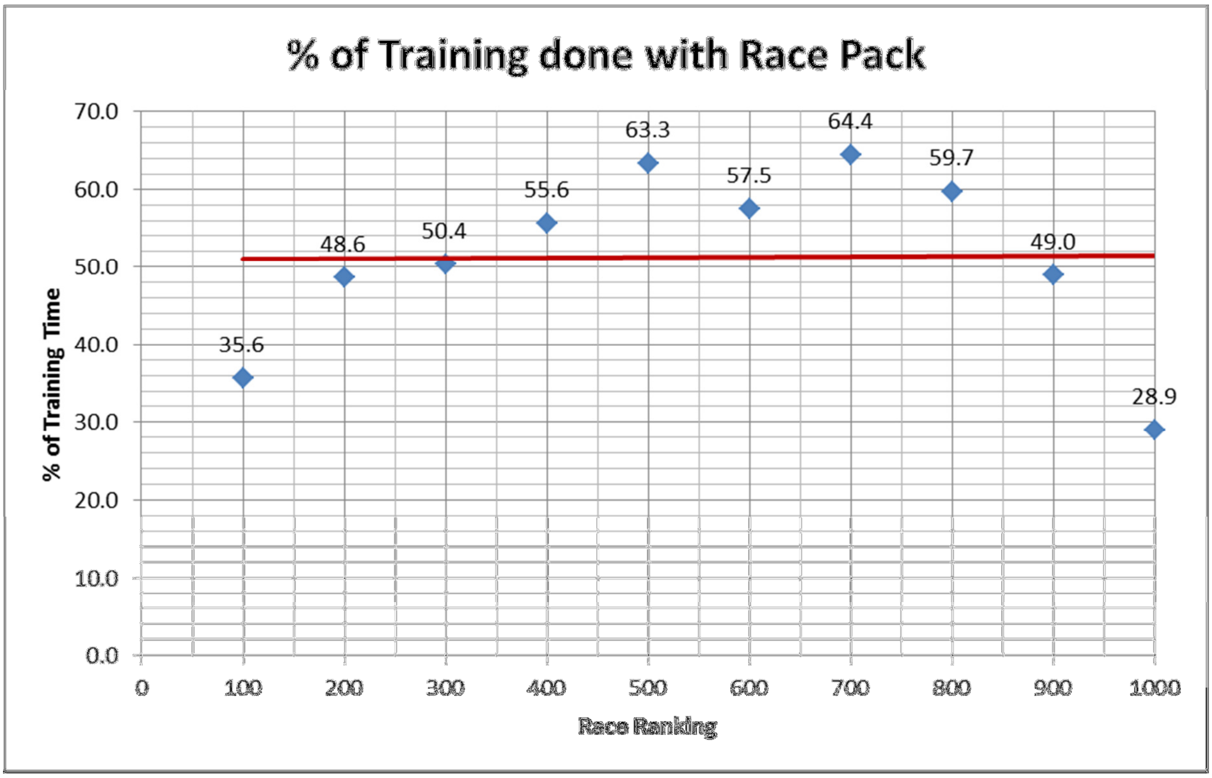
Graph 4: Race Pack Weight vs Race Ranking

This does not imply that a runner should not attempt to lighten the load even more, but that realism should be maintained in this pursuit. Individual runner budget, personal comfort and experience level, will all play decisive roles in the determination of dry race pack weight. Achieving a 6.5kg dry race pack weight will mean that a runner must forego all luxuries and will run with a limited margin for error. This is an obvious choice for those runners who approach the race with the intent to compete and not merely for the challenge. It is, furthermore, vital for a runner to maintain a realist outlook as whatever expectation an individual harbours will translate into how he or she will approach their training, pack their race pack and experience the race.

Race Pack Training

Most runners train with a race pack leading up to the Marathon des Sables. Graph 5 below illustrates the percentage of training time that runners allocate to training with a loaded race pack. The data indicates that runners train with their race packs for between 28.9% and 64.4% of the time with 51% being the median time spent across the entire performance range. It is interesting to note that the average running time spent training with a race pack, by the top 100 runners is only 35.6% and that the top 300 runners don't exceed 50.4% of training time. Equally important, is that allocating less than 35.6% of training time to running with a race pack doesn't translate into any performance benefit.

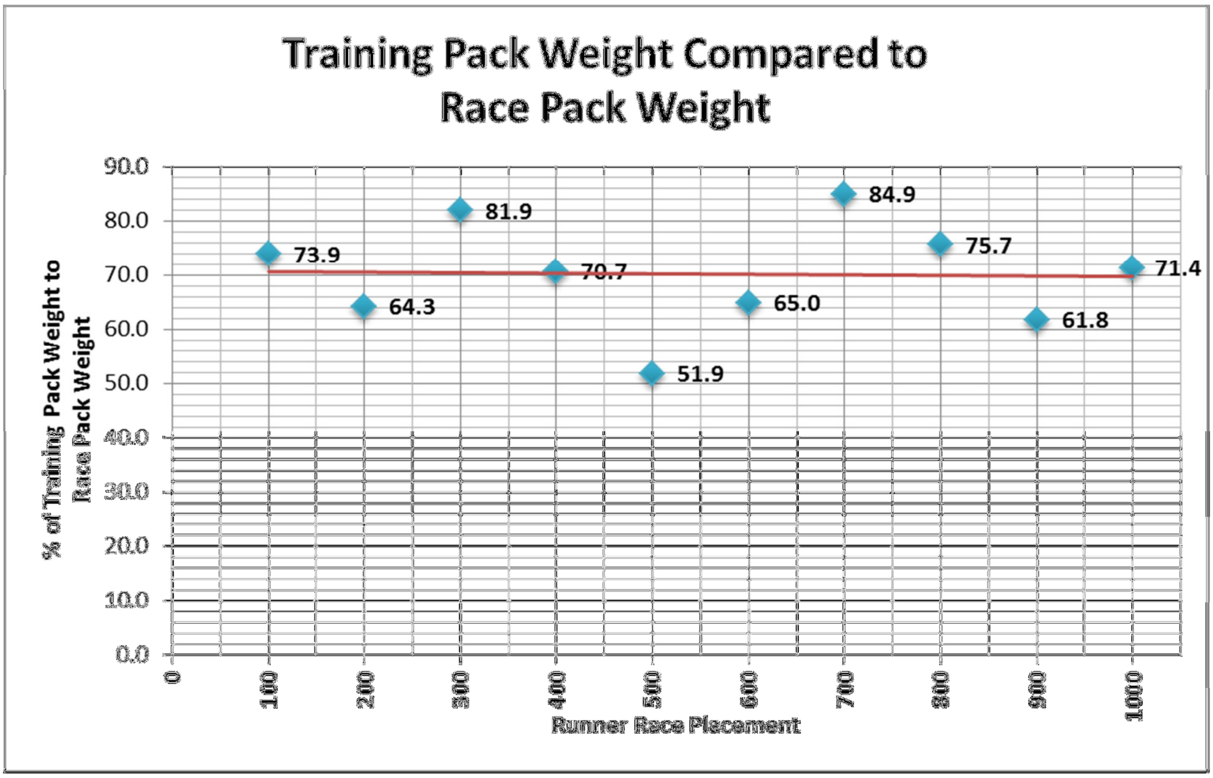
From the data, I surmise that an optimal training time allocation for training with a loaded race pack is around 45.6% (±10%), in contrast, the less optimal allocation of time is 56.2% (±7.2%). There is a point where these two time allocations intersect, and that is at 49% of training time. It is my view that an optimal training time allocation, for training with a race pack, would be around the 47% mark. For most runners on an 80km preparation week 47% would translate into 37.5km's. This would seem to indicate that a runner would train with his or her race pack during the weekly long run as well as one shorter run during the week.



Graph 5: Race Pack Training

Graph 6 below extends our understanding of the performance impact by comparing pack weight during training, to the pack weight during the race. There seems to be a clear disparity between race weight expectation and the actual race weight achievable by the runners. This speaks to an unrealistic expectation being created of the 'ultra-light' pack which the majority of runners simply don't achieve.

The data presented in Graph 6 must be contextualised in terms of race pack composition, and in particular the variable component of the race pack. There are effectively two variable weight components, the first being water weight (1.5kg) that oscillates every day with a maximum to minimum curve spread over an average 10km distance. Effectively this averages out to a 750g weight distributed over 50% of running time. The second variable, food, has a steady reduction curve over time. If we assume a 2,000kCal daily reduction (the minimum allowed per MdS rules article 24) at an optimal nutrition composition of 55% carbs, 20% protein and 25% fat, then the daily weight reduction is in the order of 431g plus 87g packaging weight (total 518g). This will effectively mean that over the course of the 250km race distance that a runner's food weight will decline at a 'steady' rate of 14.5g per kilometre or 604g per day. This figure would represent 6.7% on an average 9kg race pack or 20% of total pack weight at halfway through the race. An average weight pack weight, spread over the entire distance of the MdS, would therefore translate to 20% less than start weight. Training at this weight (7.2kg ±0.9kg) seems to be optimal with no adverse effects related to performance, although the training weight is less than race weight. The assumption on the figure above, however, is that the runner would be able to set his or her bag weight at 9kg's. If the race pack weighs more or less then the 9kg used in the calculation then the training weight component can simply be adjusted accordingly. The ratio of training weight to race weight being 70% to 90% seems to be optimal.



Graph 6: Training Pack Weight vs Race Pack Weight

From the research it was evident that the majority of runners under estimate the weight of the food they would need to carry. Optimal food weight averages (packaging included) at around 3.86kCal per gram, therefore, a 14,000 kCal race requirement would weigh in at 3.6kg's, the composition of this would be 35% fat, at 9kCal's per gram, 20% protein and 55% carbohydrates, both at 4kCal's per gram. Most runners won't even achieve this optimal ratio and would pack 65% carbs, 30% protein and 5% fat. This average diet would weigh around 4.1kg's, packaging included.

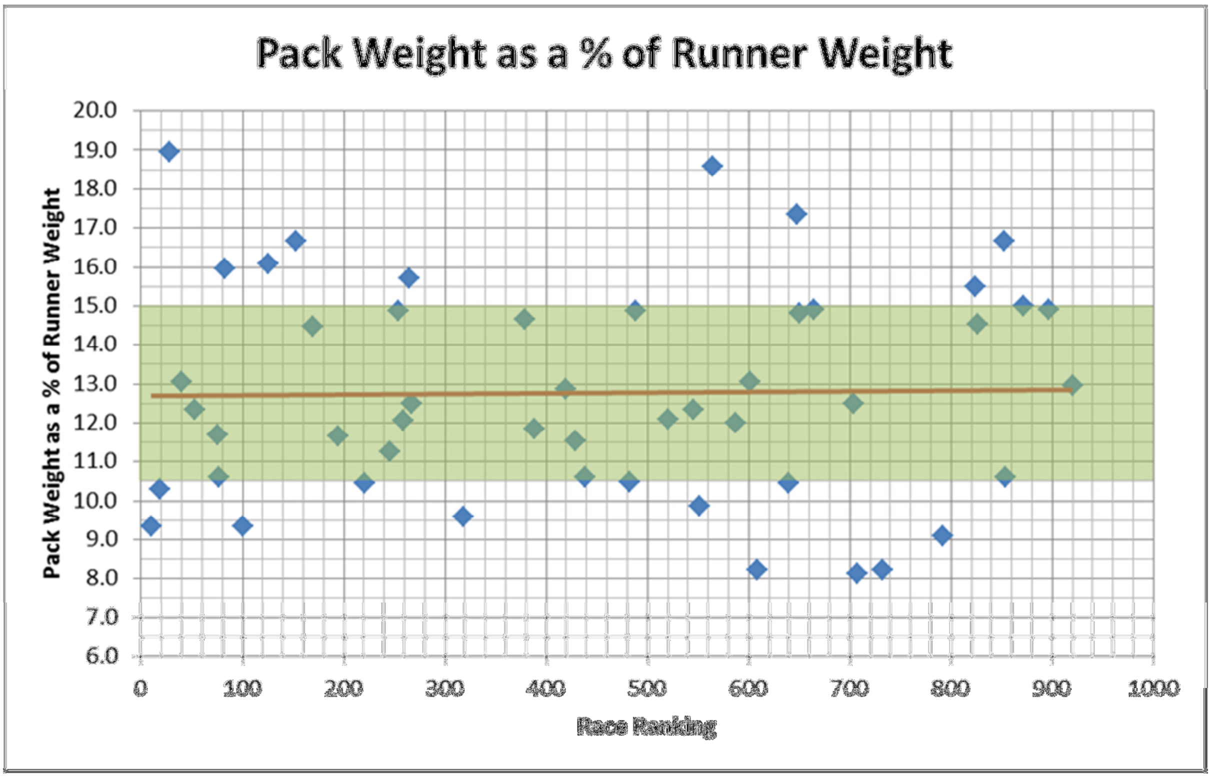
The table below will illustrate the reality of race pack weight:

	Optimal	Average
Race Pack	650g	650g
Food Weight	3,600g	4,100g
Water	1,500g	1,500g
TOTAL	5,750g	6,250g
All other equipment must fit into this number to reach a 9kg race pack weight (wet).	3,250g	2,750g

Table 3: High Level Race Pack Weight Illustration

RACE PACK WEIGHT AS A PERCENTAGE OF RUNNER WEIGHT

Unfortunately the discussion above presents only one dimension of the overall race pack dynamic. An important element that needs consideration is the relationship between race pack weight and the runner's own weight.



Graph 7: Race Pack Weight as a Percentage of Runner Weight

Graph 7 above demonstrates that a reasonable relationship between the runner's own body weight and that of his or her dry race pack can vary between 10.5% and 15.0% (12.75% ±2.25%) while maintaining a realistic level of performance. It furthermore indicates that a low percentage (8% of body weight) does not automatically translate into improved performance; neither does a high percentage (19% of body weight) translate into impaired performance. However, the closer a runner moves to the 20% of body weight mark, the higher the probability for injury (this will be discussed in another paper). The more realistic dry race pack weight to runner weight, which results in sustained performance across the entire race placement spectrum, has a range of 12.83% ± 0.07%.

This is an important figure as it sets the minimum body weight limit and associated BMI level to be achieved for sustained, and injury free, performance. If we consider a 46 year old female runner with a height of 1.66m who is able to achieve a 9kg (wet) race pack weight, and we position race pack to body weight at 12.9% then the minimum weight for the runner is 69.77kg's. For the runner this would translate into a BMI of 25.3 which is outside of the normal BMI range. If this same runner has a BMI positioned in the centre of the BMI normal range (60.62kg) and runs with a 9kg race pack, then the pack weight to body weight percentage would peak out at 14.85%. It is still, as per Graph 7, within the performance 'zone' but the runner must take great care in not sustaining an injury during, especially, the early stages of the race. For this runner an optimal weight would be between 60.62kg and 69.77kg which is 65.2kg's. This would mean that the body weight to race pack weight is at 13.8% which is roughly at the mean performance to weight level as can be seen on Graph 7. This, however, would mean that the runner has a BMI of 23.66 which is normal but well above the BMI normal centre level.

PREDICTING RACE PERFORMANCE

Assuming that a runner fits within all the weight related performance levels discussed above we are able to predict race pace performance for setting race targets. Using any form of race target prediction based upon observational or statistical data assumes a number of pre-conditions. These are:

(1) The runner has been training for the target distance, and is able to perform at that specific distance with a reasonable level of consistency,

(2) The runner has no underlying injuries or other medical conditions that presents itself during the target event, and

(3) That the runner has trained on similar terrain (trail running for instance), within similar environmental conditions (heat) and under similar physical and mental stress (distance, weight etc.)

Models of Race Performance Prediction

In predicting race performance for multi-day, ultra-endurance self-supported races, we will be considering three different models. The first model uses a runners 10km road race data as a predictor of multi-day, self-sufficiency race performance, the second model, proposed by Kirk Cureton, *et al*,[13] [14], attempts to use the runner's marathon time and predicts a race performance by considering the implication of weight. The third and final model is an observational model which I learned from Rory Coleman.

Model 1 – 10km Road Race Performance Predictor

The mean 10km road race pace to Marathon des Sables race pace is 51.15% ±14.65%. This means that a runner with a 9km/h road race pace over 10km's can expect, given sufficient purpose driven training, a race pace; of between 3.3km/h and 5.9km/h (with a mean pace of 4.6km/h). This would place the runner somewhere within the middle 400 runners (position 400 to 700). I have applied this simple relationship with a high degree of accuracy to other multi-day, self-sufficiency desert races like the Kalahari Augrabies Extreme Marathon.

This relationship has been extracted as observational data, from more than 1,000 runners having participated in five different multi-day, self-sufficiency races.

[13] Cureton, K.; Sparling, P.; Evans, B.; Johnson, S.; Kong, U.; Purvis, J., Effect of experimental alterations in excess weight on aerobic capacity and distance running performance. Medicine and Science in Sports 1978, 10 (3), 194-199.

[14] Cureton, K.; Sparling, P., Distance running performance and metabolic responses to running in men and women with excess weight experimentally equated. Medicine & Science in Sports & Exercise 1980, 12 (4), 288-294.

Model 2 – Marathon Based Race Performance Predictor Incorporating the Effect of Weight

Several studies have examined the question of excess weight and running with slightly different approaches. The one we'll look at was conducted by Kirk Cureton[15] [16] and colleagues at the University of Georgia in 1978. They found that for every 5% of excess weight, the runners covered 90 meters less over the 12-minute time trial than without the additional weight. Extrapolating this to an 18 minute 5k runner (whose race lasts one and a half times the duration of the time trial in this study), this would mean our runner would be about 30 seconds slower when carrying an excess weight of 5% of his or her original body weight. This effectively means that for every 5% increase in weight the runner can expect to run 7.5 meters slower every minute.

Based upon this data the target speed can be calculated as follows:

Step	Formula
Step 1: Runner zero weight speed in km/h	Measured Speed
Step 2: Meters covered in one hour	$Step\ 1 \times 1000$
Step 3: Meters covered every minute	$Step\ 2 \div 60$
Step 4: % Slowdown per 5% weight	$(7.5 \div Step\ 3) \times 100$
Step 5: Reduced distance every hour per 5%	$(Step\ 2 \times Step\ 4) \div 100$
Step 6: Race pack weight as a % of runner weight	Weight Input as %
Step 7: Reduction multiplier	$Step\ 6 \div 5$
Step 8: Weighted speed in km/h	$Step\ 2 - (Step\ 5 \times Step\ 7) \div 1000$

Table 4: Calculation Process

Using the process above at the hand of two examples, both runners run on a trail that simulates to some extent the conditions that will be experienced during the race. The first runner runs at 12km/h while the second runs at 9km/h. These speeds are achieved without carrying any

[15] Cureton, K.; Sparling, P.; Evans, B.; Johnson, S.; Kong, U.; Purvis, J., Effect of experimental alterations in excess weight on aerobic capacity and distance running performance. Medicine and Science in Sports 1978, 10 (3), 194-199.

[16] Cureton, K.; Sparling, P., Distance running performance and metabolic responses to running in men and women with excess weight experimentally equated. Medicine & Science in Sports & Exercise 1980, 12 (4), 288-294.

additional weight. Both runners weigh 70kg's and will run the Marathon des Sables with a 9kg race pack (wet).

	Runner 1	Runner 2
Zero weight Speed (km/h)	12km/h	9km/h
Meters covered in one hour	12,000m/h	9,000/h
Meters covered every minute	200m/min	150m/min
Percentage slowdown per 5% weight	3.75%	5.00%
Reduced distance every hour per 5% weight	450m	450m
Race pack weight as a % of runner weight	12.86%	12.86%
Reduction Multiplier	2.572	2.572
Predicted speed with race pack	10.84km/h	7.84km/h

Table 5: Race Prediction Example

Having analysed 10km road race versus 10km trail running pace of around 300 randomly selected active runners I have observed a road to trail pace reduction of between 25% and 50% (37.5% ±12.56%). By applying the median factor to the above calculation, Runner 1 is predicted to maintain a pace of 6.78km/h while Runner 2 is predicted to run at 4.9km/h. I am, further, of the opinion that the unadjusted predicted speed with race pack as calculated above dictates that Runner 1's maximum speed would be 10.84km/h and Runner 2's 7.84km/h. This maximum speed would be attainable over short distances and does not represent a sustainable pace.

Model 3 – MdS Observational Race Performance Prediction Incorporating Weight

This model simply states that a runner at the MdS will take 1.4 times longer to run a marathon distance with a 4kg race pack. It furthermore states that for every additional kilogram of race pack weight, a runner will add an additional 25 minutes to his or her marathon time. If we assume that a runner will be able to run a marathon at a sustainable pace of 9km/h and that this runner will run the MdS with a 9kg race pack, then this runner will be able to sustain a MdS race pace of 4.86km/h.

MODEL SUMMARY

The three models, each approach race performance prediction from a slightly different angle, yet deliver for the same set of variables a fairly narrow race prediction. A runner running a road race at 9km/h without weight will, according to the first model, be able to sustain a race speed of 4.6km/h ±1.3km/h, according to the second model the runner would be able to sustain a race performance of 4.9km/h ±1km/h and according to the third model race performance is predicted to be 4.86km/h. The combination of all three models seems to indicate that a race pace of 4.79km/h can be sustained throughout the race and that this runner would have a maximum speed ceiling of 7.84km/h. This ceiling speed will not be sustainable but will be reachable for brief periods within the race.

CONCLUSION

From the data it is clear that a certain level of weight loss is preferred for athletes that participate in multi-day, ultra-endurance, self-supported race events like the MdS, KAEM, etc. However, contrary to what is promoted by many trainers, and running coaches, there is no need for an athlete to reach towards the bottom end of the BMI scale, as a matter of fact, a BMI of 20 and below seems to have little, if any, value when measured in-terms of running performance. It was somewhat surprising to find top 300 runners with a BMI between 25 and 27 as this BMI indicates that a runner is overweight. What was even more surprising was the fact that runners with a BMI below 20.5 were not able to secure a place in the top 500. This would seem to indicate that, for the ultra-endurance, multi-day, self-supported runner, being slightly 'overweight' is better than being 'lean'.

As for body fat percentage, male and female runners seem to perform somewhat differently, as expected. For males there appears to be a constant performance level across the entire performance range when they have a race start body fat percentage of between 16 and 24 percent. A body fat percentage below 16 and above 24 percent seems to exclude a runner from the top 150 positions, with higher body fat percentages above 26 percent being limited to runners ending in the last half of the field. For female runners the performance band is much narrower, with optimal performance derived at with a body fat percentage between 27 and 30 percent. Those female runners with a body fat percentage below 27 or above 30 appear to be limited to ending in the last 150 positions.

Determining the ideal race weight and body fat percentage must start from the runner's realistic race pack weight. For the majority of the MdS field a realistic dry race pack would weigh in at around 9.125kg ±0.273kg or 10.625kg ±0.273kg wet. Given this arbitrary race pack weight and the realistic performance range of dry race pack to body weight percentage of 12.83% ± 0.07%, the ideal body weight of a runner carrying a 9.125kg dry race pack would be 71.12kg.

Performance, however, appears to be fairly constant with a race pack weight to body weight relationship of between 10.5% and 15% (12.75% ±2.25%). In real terms this means that the ideal runner weight should fall somewhere between 60.8kg and 86.9kg (73.85kg ±13.05kg). The reality is that, given the body fat percentage performance level of (20% ±4% for males and 28.5% ±1.5% for females) that males will have a measurable body fat of 14.77kg ±2.95kg and women 21.05kg ±1.11kg. If we return to our BMI performance range of between 21.5 and 24.9 (23.2 ±1.7) we can calculate the personal range that incorporates both weight and body fat percentage.

A male with a height of 1.78m and a female with a height of 1.66m, both 45 years old, will have the following weight range.

$$\boldsymbol{Mass\ (kg) = BMI\ \times Height\ (m)^2}$$

Given this formula, the range weight range for the male is 73.5kg ±5.4kg and for the female runner 63.9kg ±4.7kg. Given our Body Fat Percentage formula, the body fat range for both this male and female runner is 21.9% ±3.81% and 32.8% ±6.9% respectively. As can be seen, both the male and female runner is within the performance body fat percentage range given the weight range.

Given the data, the implication of weight loss and body fat reduction should be carefully considered; taking into consideration various factors, including race pack weight.

There also seems to be some disconnect between the race pack weight anticipated pre-race, and which runners train with, and that which can be realistically arrived at on the start line. It is, therefore, important to start with a realistic race pack weight for training purposes, and if a runner is able to make weight gains pre-race this will translate into its own benefit. However, race weight also has more than just an effort element to consider, and any gains made in-terms of weight has to be considered in-terms of the psychological and/or physical cost of the reduction. Some level of comfort, or ‘excess’ can translate into a mental benefit that eliminates the cost of the extra weight altogether. This would imply some surrogate benefit opposed to a real benefit, but the overall result has been observed. When it comes to making those tough decisions about weight the following reality, derived from the 3rd prediction Model can be used. Each gram over the 4kg pack weight will cost you 1.5 seconds per gram per 42.2km distance or 8.9 seconds over the duration of an event like the Marathon des Sables. Weight reduction might be far more important for the top 10 runners, than for those runners who run somewhere further down in the overall rankings.

In essence it comes down to, do I take a stove of 15g? Will the comfort, lack of effort and psychological benefit that can be derived from the stove, outweigh the 2m14s race cost?

As this is a discussion paper, your thoughts and input around this will be greatly appreciated. Any comments or discussions on this can be emailed to me at: genis@push2extreme.com

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