Study of Some Performance Factors in Long Distance Race for Senegalese Runners using Matlab and Kinovea

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Abstract: ***In this article, we evaluate different factors of performance in long-distance running. Anthropometric measurements, biomechanical and kinematic analyzes obtained using treadmill videos and physiological measurements performed under standardized conditions on athletes allowed us to evaluate variables related to the race to explain the performance achieved during international marathons. Fourteen (14) athletes participated. The goal of this work was to enable Senegalese athletes to better prepare and improve their performance in the hope of finally competing with the world elite. At the end of our study, we have highlighted some essential variables that can allow athletes to improve their level of performance. The results demonstrated that a suspension time of stride must be increased from 0.3 to 0.5 and cushioning time to be reduced from 0.35 to 0.15.***

Keywords: maximum aerobic speed, performance, stride quality, matlab, kinovea

1. Introduction

The observation of the curve of performance of running according to the years from 1908 to the present day has shown a great evolution of performance at the international level, resulting of a long process of work and research specialists, athletes, coaches and scientists, from different nations around the world.

This study is a contribution to performance in long distance run.

In recent years, long distance races and the marathon have become a reality in Senegal; also, the half marathon and the marathon have become a tradition in Senegal. However Senegalese athletes seem to have difficulty adapting to the specific requirements and pace of performance imposed today by athletes of Kenyan and Ethiopian origins [Billat et al., 2013]. The goal of this work was to enable senegalese athletes to better prepare and improve their performance in the hope of finally competing with the world elite.

Thus, what are the parameters and variables of the performance to be improved to increase the performance of our athletes in long distance run?

We will study the morphological characteristics as well as the race technique of the Senegalese athletes of our study in comparison with athletes of international level.

2. Materials and methods

We first performed a laboratory study on a population of fourteen (14) subjects at first and then we collected data from distributed questionnaires and fact sheets to be completed by the different athletes. The inclusion factor in the study was to be specialized in endurance races and to have already participated in at least one of the international marathons organized in Dakar. The laboratory test was carried out at National Institute of Popular Education and Sport (INSEPS: Institut National Supérieur de l'Education Populaireet du Sport) in Dakar. We used a treadmill and video recording to collect the race data needed for our study. For the anthropometric and biometric parameters, we took the values of skin fold measurements, segment length and body biometrics. The race effort test started with a slope of 1% and a speed of 8 km/h for 2 minutes; the speed was increased by 0.5 km/h and this every minute until exhaustion. We recorded the maximum speed and heart rate every minute and at the end of the test which corresponds to the actual maximum heart rate observed. We also took the field performances of the same subjects such as the time on the 10 km, the half marathon and the marathon.

a :bending angle of the forearm on the runner's arm 20H

b :Image of the angle of the bust relative to the vertical and that of the foot relative to the ground of the runner 20H

c: Image of the angle of the back leg from the ground at the impulse of the 21H

Figure 1: Video Analysis of Treadmill Running

All measurements have been processed on Matlab R2017b which is a platform for statistical processing and powerful data analysis. Kinovea motion analysis, a free software application for the analysis, comparison and evaluation of sports and training, was used to obtain the biomechanical data [kinovea.org]. Below we show the means and standard deviation of Maximal aerobic speed (MAS) measurements.

Table 1: mean of some measurements
Middle-distancelong-distance

MAS (km/h)	18,2 ± 0,59	19,7 ± 1,57
Age (years)	25 ± 3,12	26 ± 2,92
Height (cm)	180 ± 5,98	173 ± 6,32

Table 2: Percentages of the distribution of the different stride phases, their frequency and amplitude

Subject	Pulse	Suspension	Cushioning	Frequency	Amplitude
12H	41,18	29,41	29,41	180	1,30
17H	42,86	28,58	28,58	180	1,30
16H	28,58	37,14	34,28	174	1,34
09H	36,67	46,67	16,67	180	1,30
02H	42,86	28,58	28,58	174	1,34
11H	21,62	45,95	32,43	156	1,26
13H	42,86	28,57	28,57	186	1,26
07H	42,86	28,58	28,58	168	1,39
18H	21,62	45,95	32,43	174	1,34
20H	36,11	27,78	36,11	156	1,50
05H	36,11	27,78	36,11	168	1,39
10H	42,86	28,58	28,58	168	1,39
26H	37,5	25	37,5	156	1,50
21H	23,33	33,33	43,33	180	1,30

3. Results

In our study, it was the participants in the long distance races who had the Maximal aerobic speed at the half marathon and marathon. Compared to the quality of the stride, the footsteps of the best athletes with the highest MAS are around 180 steps per minute.

In Fig. 2, we found a significant correlation between the cormic index and the percentage of the maximum aerobic speed (%MAS) that can be mobilized throughout the race by the subjects during the competition.

The cormic index is the ratio of sitting height to standing height multiplied by 100. Its values should be between 48 and 55.
In the interpretation we have 3 possible cases:

First case; the index is greater than 53%, which means that the subject has a long bust and short legs; it's the macrocorms.
Second case; the index is between 51 and 53%, which means that the arms and legs are perfectly proportioned. It is the metricorms, it is the model of the man of Vitruvius (Leonardo Da Vinci).

Third case; the index is less than 51%, which means that the subject has a short bust and long legs. It's the brachicorms, they are known to perform well in running.

This correlation could be explained by the fact that a shorter bust is lighter and therefore easier to move. And that long legs can have great strides.

In our study, the average cormic index of our subjects is 48.77 and the 82% are brachicorm type. This means that most of them have their favorite discipline, running.

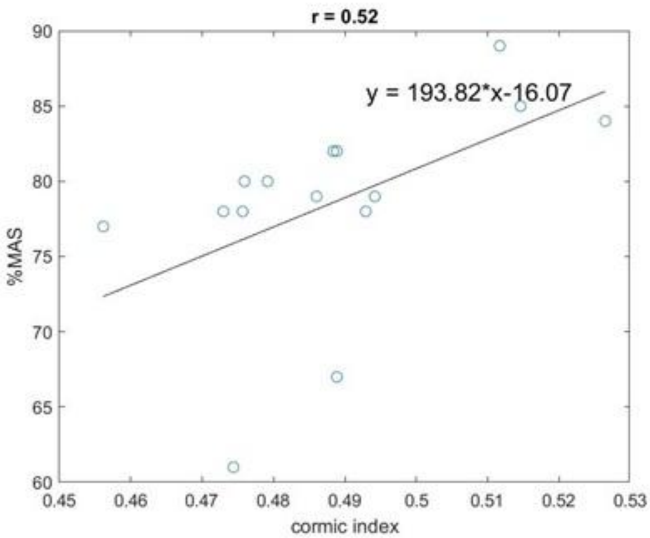

Figure 2: Explanation of %MAS by the cormic index

In Fig. 3, we found a perfect correlation between the percentage of the pulse time and that of the suspension.

The pulse is the phase of the stride that is between the moment when the foot is located below the center of gravity and the moment when it leaves the ground.

The suspension is the phase where the runner has no contact with the ground, it is also called the flight phase.

The antagonistic evolution that exists between the pulse and the suspension could be explained by the notion of power. A power is the product of the force by the speed ($P = F x V$).

The force $F = m.a$ implies that $P=m.a.V$ and $a$is the acceleration, which is also the result of the derivative of the speed. From where $a=(V - V_i)/(t - t_i)$ and we will have:

$P= mV[(V – V_i)/ (t - t_i)]$, if $t_i= 0$ and $V_i=0$, then the power P would be equal to $P= mV^2 /t$.

In this reformulation, we find that the speed is squared. This testifies to the level of importance of speed in the production of power. On the other hand an increase of the time would negatively affect the norm of the power. This means that the shorter the pulse, the greater the gain in terms of power becomes, which is worth a greater amplitude hence a proportion of the longer suspension time.

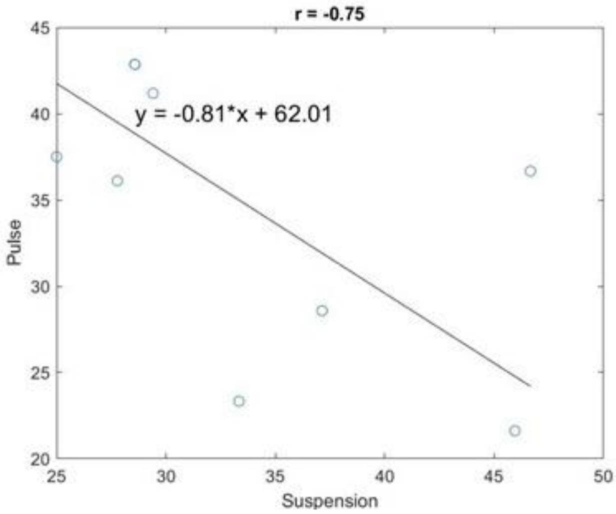

Figure 3: Diagram of dispersion between the proportion of suspension and the proportion of the pulse in the duration of the stride.

We found that the MAS correlated significantly with the proportion of cushioning time (Fig. 4).

Since all the subjects had run at the same speed (14 km/h), we considered having identical proportions between them. But this is not the case, here the results showed a rational variation in the proportions of the cushioning phase compared to the MAS (fig. 3). This states that there is a relationship between the MAS of a subject, and the percentage of the time of the straightening phase of his stride.

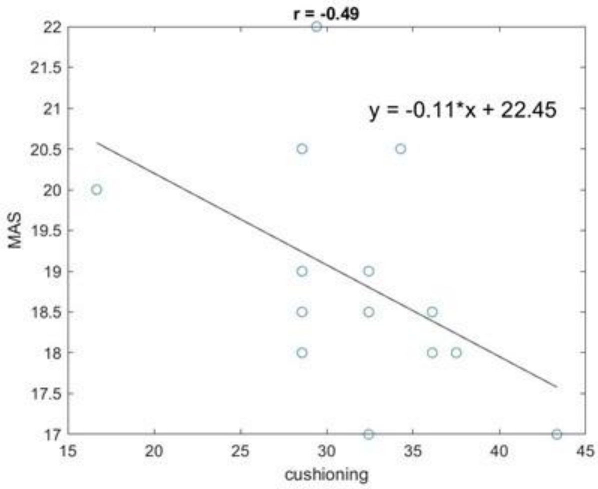

Figure 4: Relationship between the MAS and the proportion of cushioning time

In Fig. 5, the frequency of the stride is the number of supports performed in a running per unit of time; it is often expressed in hertz; which is equivalent to one cycle per second.

In our study, we expressed this frequency in stride/minute.

The MAS is explained with a correlation of 44% by the frequency of the stride.

With fourteen data, the degrees of freedom would be 13 (degree of freedom, df = 13). Using 95 percent critical values of the Sample Correlation Coefficient table with $df = 13$, we find that the critical value is 0.5139. This means the critical values are really ±0.5139. Since R < 0.5139, R is not significant. This correlation is weak.

Yet, it turns out to be more economical to increase its speed by frequency rather than amplitude. In general, our study shows that the fastest subjects, i.e. those with larger MAS, are those with the highest stride frequencies and this could be explained by our analysis. Moreover, A 91% increase in speed is equivalent to an increase in stride amplitude of 83% while the frequency has increased by only 10% (IAAF, New studies in athletics, 1985). Here we find that a small increase in frequency gives a much more effective result than an increase in stride over speed.

The free lower limb creates leverage, such as a pendulum, in order to increase the speed of propulsion of the body forward, so this mechanism does not require significant work of the muscles as suggested in [Weber W. & Weber E., 1992]. This is done as many times as the number of strides. Its effectiveness will be determined by the speed of replacement of the legs, which would depend on the speed of rotation of the thighs on the transverse axis of the pelvis, hence the frequency of the stride. As a result, the period in which the leg is flexed on the thigh is where the muscles perform less effort compared to the moment of the impulse phase. And the effectiveness of this action would depend on the length of the thigh, which would increase the moment (M) of the force (F) of rotation applied to the lower extremity (knee) of the thigh compared to the upper end (hip). Hence the formula: M = Thigh length * F;

The origin and intensity of the force (F) depends on the pace of the race; it mainly involves the gluteal muscles, the abdominal muscles and the gravitational force of the Earth depending on the different phases of the race; According to 3 situations:

- When the rider is in a deceleration phase or at a pace too low; the sway of the leg is controlled and in this case, the gluteal muscles will create a force in the opposite direction to the movement of the limb with an intensity lower than its weight.
- When the runner is in an acceleration phase; the abdominal muscles produce a force in the same direction as the direction of movement of the lower limb with a greater intensity.
- When the speed is constant; we have a negligible work of glutes and abdominals in relation to this movement.

The last case seems more economical, because we have a less important work of the concerned muscles. Hence a constant race could be considered the most economical. In the race, the frequency of the stride multiplied by the amplitude determines the speed of the movement. An athlete who wants to improve his personal record in any distance must do something to improve the product of both elements.

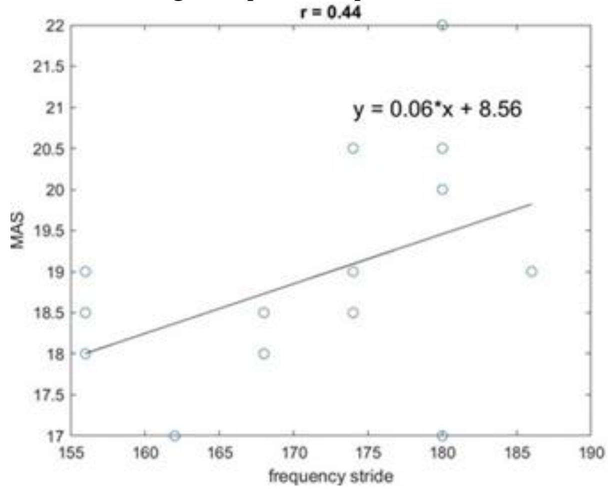

Figure 5: Relationship between MAS and Stride Frequency

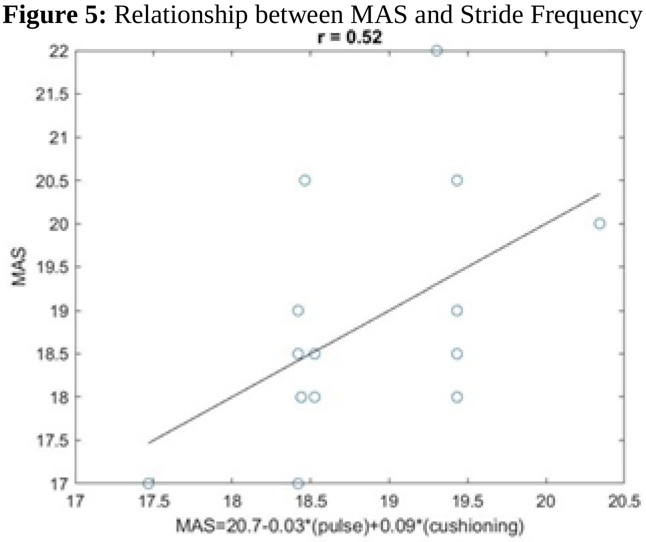

Figure 6: Multiple linear regression: Explanation of the MAS by the proportions of the pulse time and that of the cushioning

We obtain a correlation of 52% in the case of a multiple regression (Fig. 6) where we explain the MAS by the proportions of the pulse and cushioning time versus 49% between the MAS and the cushioning only. This increase shows that it is a whole process that enters into force for better MAS.

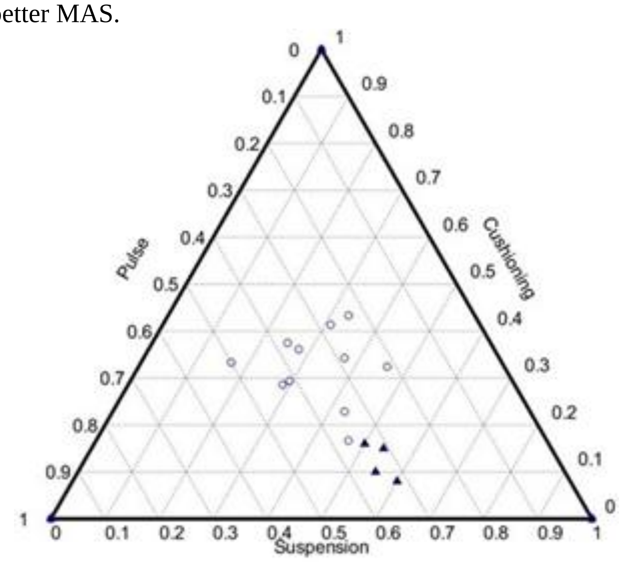

Figure 7: Ternary diagram giving the proportions of the different phases of the stride in its duration visualized in outline drawing for senegalese athletes (o) and international high-level athletes (▲).

We use the ternary diagram, which is a two-dimensional graph that allows us to represent three exclusive variables (the sum of which is always 100%); and can compare the race data of Senegalese athletes to international high-level athletes. These data are the proportion of pulse time, proportion of suspension time and proportion of cushioning time.

When international high-level athletes put on average 55% of suspension time and 15% of cushioning time, the senegalese athletes of our study put 30% of suspension time and 35% of cushioning time (Fig. 7).

In order to obtain a more efficient race, the accent must be put on the stride especially in the suspension phase and to a lesser extent in the cushioning phase.

To reach the high level, it will be necessary for the senegalese runners to optimize the ratio stride length with respect to the frequency. In the second point, it is the cushioning time that depends on the elasticity of the muscle and which determines the flight time, ie the critical ratio which consists in remaining the minimum of time on the ground and having the maximum of flight time. This is well confirmed by [Billat et al., 2003], which characterizes the high performance runners by their amplitude ratio on the frequency of the stride but also cushioning time compared to the time of flight. This is not yet the case with the senegalese runners of our study.

4. Conclusion

The results of our study show that for optimal long distance performance, senegalese runners should consider several factors. Because if running seems so simple, the large number of variable that brings into play makes it a very complex activity. Thus, for optimal performance, it is necessary to have an optimal stride frequency associated with a lower energy cost, to include more specific endurance sessions and to readjust the body mass index appropriate to the distance. The Senegalese runners of our study have to improve during the stride, the suspension and cushioning phase.

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