How Does the Increase of Body Mass and Ageing Affect Sprinter's Results in a 100 m Run?

¿Cómo Afecta el Aumento de la Masa Corporal y el Envejecimiento a los Resultados del Velocista en una Carrera de 100 m?

Natasa Janjic[1]; Darko Kapor[2]; Dragan Doder[3]; Predrag Rasovic[1] & Lana Radisic[3]

SUMMARY: The career of a sprinter is analyzed with U. Bolt achievements as an example. The effects of the increase of body mass and ageing are discussed within the framework of the polynomial models for the velocity, muscular isometric force and age. The analysis presented demonstrates the influence of the BM factor in analyzed racing. The nonlinear increase of the BM for 9 kg in the period 2009 – 2017 in was one of the reasons of Bolt's unsuccessful attempt to repeat or confirm the time 9.58 s. Another limiting factor was the fact that due to the age, Bolt was not able to increase isometric muscular force which, after the year of maximal efficiency (2009) decreased.

KEY WORDS: Ageing; Increase of body mass; Isometric Force; Polynomial Model; Velocity.

INTRODUCTION

In the previous paper (Part I) we attempted to quantify the influence of the change of sprinter body mass (BM) to the final time of the run, inspired by the work of Hernández-Gómez *et al*. (2017). They studied the effects of the increase of BM and the age (G) of the sprinter. These factors act integrally, but in the paper their effects on the final time and sprinter velocity have been considered separately.

One must keep in mind how the sprinter efficiency changes with age: First it increases till some maximal limit which can be approximately determined, and then it decreases. This age limit is individual and it depends on gender and on some psychological, hereditary, kinematical-dynamical and physiological factors. Some of these factors are considered in the papers (Charles & Bejan, 2009; Coh & Bosnjak, 2010; Doder *et al*. 2012, Alacid *et al*. 2012a,b; Malacko *et al* 2015; Janjic *et al*., 2017a; Krzysztof & Mero, 2013; Varlet & Richardson, 2015).

The aim of the present research is to define approximately the limit of the maximal efficiency in terms of the age in years G, more precisely in terms of the change of isometric motor force with age. We shall use the models proposed in earlier papers (Janjic *et al*., 2014, 2017a,b, 2019; Doder *et al*.; Bayat *et al*., 2014; Merellano-Navarro *et al*., 2021).

The test of our approach will be the analysis of some of the results by U.Bolt as an obvious example of the simultaneous non-linear increase of BM and age before Olympic or World competition, from Beijing 2008 to London 2017 (The authors stressed in Part I that the calculations are based on data from various sources,so they should be treated as only approximate, yet sufficiently illustrative.)

MATERIAL AND METHOD

In part I, we tried to quantify the influence of the body mass and here we study the effect of the age onto the final time tfas the crucial result. The authors conducted their research ethically, according to international standards and as required by the journal as described in Harriss & Atkinson (2009).

[1] University of Novi Sad, Faculty of Medicine, Orthopaedic Surgery and Traumatology Clinic, 21000 Novi Sad, Serbia.
[2] University of Novi Sad, Department of Physics, Faculty of Sciences, 21000 Novi Sad, Serbia.
[3] Department for Sport and Sports Medicine of Province, 21000 Novi Sad, Serbia.

It is well known that for each sport result, basic importance lies in the force which produces static power and which increases during the adolescence and growth of the sportsman with the age until a maximal limiting value, after which it begins to decrease. This limit is a hypothetical one since it is individual and depends on numerous factors. In our opinion, this limit should be understood as an expected value (expressed in term of years) which signals that there begin to arise biochemical and mechanical changes opposite to the ones appearing during the growth and which can lead to various defects or deformations. So it should not be understood as a limitation for achieving the top results. This is confirmed by many situations in sports where elder beat younger, or vice versa. One obvious example is the World Athletic Championship 2017 in London, were U. Bolt (age 31) lost 100m run race to American sprinters J. Galetine (36) and C. Coleman (23). This example, as well as many others clearly confirms our assumption that this limit of maximal efficiency is an indicator of the possible decrease of the force and velocity of the sprinter.

If a sprinter wishes to resist to the decrease of muscle force and velocity, i.e. power due to ageing, he must induce positive changes within his organism due to overload by increasing the intensity and range of existing exercises, or by introducing the new ones. New exercises for developing power which should be generated in muscles must be approximately in the trend of development and function of the body composition: 40 % of muscular mass, 20 % of bones, 10 – 15 % subcutaneous fat tissue and 20 – 25 % of the rest (internal organs, cartilage, ligaments, tendons etc). If it is not, body composition will be unbalanced so that the amount of the fat tissue will be increased on account of muscular mass, producing the effect opposite to the expected one.

In order to determine the efficiency limit as well as development isometric muscular force (IMF) F depending on the age G, it is necessary to define and analytically present the functional dependence F =f(G) for particular muscular groups. To realize that, we used the results for male sprinters from previous work (Doder *et al.*). In this work, for a sample of 1857 sportsmen from 20 different sports divided into age groups of 8 – 30 years, dynamometric average value of IMF of various muscular groups was measured: left and right hand flexors (LHF and RHF), upper-body flexors (UBF) and

extensors (UBE) and leg extensors (LE). Measurement results were used to fit with the statistical programs Excel and Origin 6.1 the equations of the dependence of IMFF on the age G (in years).

The equations for particular muscular groups whose sum gives the total resulting force are:

LHF $F = 6.088-3.152 G + 0.616 G2-.0.0178G3$

RHF $F = 10.262-3.966 G + 0.746 G2-.0,019G3$

UBF $F = -36.66-10.466 G - 0.139 G2-.0,003G3$

UBE $F = 48.057-10.761 G + 1,847 G2-.0,046G3$

LE $F = -5.489-8.041G + 2.495 G2-.0,019G3$

Calculating the derivative of the function F(G) from (1) for each listed muscular group, one can determine the age G_0 representing the efficiency limit. The sum of the particular group values of IMF for each age G represents the factor of the static force defined as the endurance ability for particular resistance.

RESULTS

We shall apply above presented theory to the results of Usain Bolt in 100m run in the period 2008 – 2017 in order to answer how much the factors of increased BM and ageing contributed to the fact that U. Bolt never succeeded to repeat or improve his world record (9.58 s) although the experts were very optimistic in their predictions. To provide proper quantification, we shall consider each of the factors separately.

In order to determine the age corresponding to the efficiency limit (EL) G_0 as well as developmental isometric force F for the relevant muscular groups, our initial point was the defined and analytically presented functional dependence F=f(G) (1) whose sum gives the resulting force. We determine efficiency limit by calculating the

Table I. The variation of the efficiency limit G_0 of the corresponding IMF F with the age, for various groups of muscles.

Size	LHF	RHF	UBF	UBE	LE	Taken as result
G_0 (years)	22.04	23.15	23	23.44	24.20	23
F [N]	77.27	81.82	94.03	217.94	429.23	900.28

Table II. The variation of IMF F with the age, for various groups of muscles.

Place, year	G (years)	BM [kg]	Isometric force F [N]					Sum [N]
			LHF	RHF	UBF	UBE	LE	
Berlin 2009	23	86	77.27	81.82	94.03	217.94	429.23	899,69
London 2012	26	93	71.64	76.72	88.76	208.35	424.47	869.94
Beijing 2015	29	93	53.28	58.37	76.81	167.42	370.55	726.43
London 2017	31	95	32.54	37.26	64.83	119.05	301.92	555.60

derivative of (1) and also calculate the value of the isometric force at that age. It is presented in Table I.

Small differences in the value for G_0 appearing for different muscular groups indicate that efficiency limit is achieved gradually and not instantaneously. However, further analysis will be based on a unique efficiency limit value of G_0=23 years with corresponding IMF 900.28 N. Now we use the expression (1) for the age dependence of IMF for various runs (Table II).

DISCUSSION

We are reminded that U. Bolt achieved the world record (9.58 s) at the age of 23 years when, according to our calculations, he was in the phase of maximal efficiency. In order to repeat or improve this result, he must produce the necessary energy within his organism by causing positive changes by overload. This overload can be acquired by increasing the scope of existing or new exercises and by the increase of the BM. Bolt decided that by nonlinear increase of BM in the period 2009 – 2017 he will increase the force of the reflexive impulse with a fast and strong hit of the foot at the ground.

We have already mentioned that he did not manage to reproduce or improve his record result and we now continue with a possible explanation why it did not happen. We apologize for repeating some of the arguments from the Part I. Let us focus on the comparative analysis on two runs: one with the mass of 80 kg and wind velocity + 0.9 m/s (Berlin 2009) and the other one with BM equal 95 kg and wind velocity – 0.8 m/s (London 2017). It is clear that Bolt with BM of 95 kg and a front wind can achieve the same velocity as with the BM of 86 kg and a back wind, only if he invests more static power into the motor force. This power comes from the organism itself due to the resulting intensity of the isometric forces of individual muscular groups. In the year 2009, when Bolt established the world record, he was at the age of 23 (age of maximal efficiency) and according to our results this force was equal to 900.28 N, while in 2017 its value was 555.69 N, so 341.57 N less.

The approximate equality of the time due to the effect of BM in the accelerating phase of the run, for both runs, implies BM increase and the change of the wind direction was not an obstacle that Bolt could not overcome by introducing additional physical strength. In the second phase of the run, on a distance of proximately 20 m, there is no acceleration. According to eccentric – concentric reversible cycle, this means that at the moment when the muscular extension stops and contraction begins, the muscular force is increased in isometric conditions (Zaciorski & Kramer, 2009). No work is performed in this case, but due to the contraction state there exists a comparatively large spending of the energy reserves in the cells of muscular tissues. To sprinters, it causes fatigue, which arises during and after statically active stress (Opavski, 1982). It is clear that the fatigue grows with the length of the uniform velocity phase. So, in London 2017, Bolt with 95 kg ends the second phase tired, contrary to the run of 2009 (86 kg) when he realized the uniform motion phase in the part of the path between 80 – 100 m. In 2017, he entered the third phase (deceleration) at about 80 m when the finish was expected, but instead he stops and slows down as if he had lost his breath. This deceleration, according to Coh & Bosnjak is the consequence of central and peripheral fatigue of the peripheral nerves and metabolic processes in the sprinter's muscles. In our opinion, there arose an acute fatigue due to sudden and too abundant spending of the energy in a short time interval, the energy that the organism could not compensate through its organs. Bolt spent the physical strength to overcome the inertia due the increase of BM and decrease of IMF due to ageing.

In this way we have demonstrated that hitherto neglected effects of BM increase and ageing onto the final time of the run must be taken into account.

RESUMEN: La carrera de un velocista se analiza con los logros de U. Bolt como ejemplo. Los efectos del aumento de la masa corporal y el envejecimiento se discuten en el marco de

los modelos polinomiales de velocidad, fuerza isométrica muscular y edad. El análisis presentado demuestra la influencia del factor MC en el análisis en las carreras. El aumento no lineal de la MC para 9 kg en el período 2009 - 2017 fue una de las razones del intento fallido de Bolt de repetir o confirmar el tiempo 9,58 s. Otro factor limitante fue el hecho de que debido a la edad, Bolt no fue capaz de aumentar la fuerza muscular isométrica que disminuyó luego del año de máxima eficiencia (2009).

REFERENCES

Alacid, F.; Muyor, J. M.; Alvero-Cruz, J. R.; Isorna, M. & López-Miñarro, P. A. Anthropometric indexes in young elite male sprint canoeists. *Int. J. Morphol., 30(2)*:579-82, 2012b.

Alacid, F.; Muyor, J. M.; Vaquero, R. & López-Miñarro, P. A. Morphological characteristics and maturity status of young female sprint and slalom kayakers. *Int. J. Morphol., 30(3)*:895-901, 2012a.

Bayat, P. D.; Ghanbari, A.; Moradi, M. & Raoofi, A. The effects of age and sex on brain volume. *Int. J. Morphol., 32(4)*:1477-83, 2014.

Charles, J. D. & Bejan, A. The evolution of speed, size and shape in modern athletics. *J. Exp. Biol., 212(Pt. 15)*:2419-25, 2009.

Coh, M., & Bosnjak, G. Neuro-muscular characteristics of maximal sprinter speed. *Sport Logia, 6.*1, 2010.

Doder, D. V.; Babiak, J. J.; Janjic, N. J. & Doder, R. Z. Isometric force development of some muscle groups in athletes. *J. Strength Cond. Res., 26(1)*:293-8, 2012.

Harriss, D. J. & Atkinson, G. International Journal of Sports Medicine - ethical standards in sport and exercise science research. *Int. J. Sports Med., 30(10)*:701-2, 2009.

Hernández-Gómez, J. J.; Gómez, R. W. & Couder-Castañeda, C. Impact of mass gain, tailwind and age on the performance of Usain Bolt from Beijing 2008 to Rio 2016. *Eur. J. Phys., 38(5)*:054001, 2017.

Janjic, N J.; Kapor, D. V.; Doder, D. V.; Petrovic, A. & Jaric, S. Model for assessment of the velocity and force at the start of sprint race. *J. Sports Sci., 35(3)*:302-9, 2017a.

Janjic, N. J.; Kapor, D. V.; Doder, D. V.; Doder, R. Z. & Savic, B. V. Model for the determination of instantaneous values of the velocity, instantaneous, and average acceleration for 100-m sprinters. *J. Strength Cond. Res., 28(12)*:3432-9, 2014.

Janjic, N.; Kapor, D.; Doder, D. & Savic, I. Evaluation of the final time and velocity of a 100 m run under the realistic conditions. *J. Hum. Kinet., 66*:19-29, 2019.

Janjic, N.; Kapor, D.; Doder, D.; Petrovic, A. & Doder, R. A model for determining the effect of the wind velocity on 100 m sprinting performance. *J. Hum. Kinet., 57*:159-67, 2017b.

Krzysztof, M. & Mero, A. A kinematics analysis of three best 100 m performances ever. *J. Hum. Kinet, 36*:149-60, 2013.

Malacko, J.; Doder, D.; Stankovic, V.; Dokmanac, M.; Savic, B. & Doder, R. A Comparative analysis of the morphological characteristics of elite karatekas, judokas, taekwondoists, boxers and wrestlers. *Int. J. Morphol., 33(1)*:245-50, 2015.

Merellano-Navarro, E.; Olate-Briones, A.; Norambuena-Mardones, L.; Rojas-Ramos, V.; Plata-Luna, M. A.; Faúndez-Acuña, J. Y.; Moraga, J. C.; Escobedo, N. & Herrada, A. A. Reduced naïve T cell numbers correlate with increased low-grade systemic inflammation during ageing and can be modulated by physical activity. *Int. J. Morphol., 39(3)*:789-96, 2021.

Opavski, P. *Osnovi Biomehanike.* Beograd, Naucna Knjiga, 1982.

Varlet, M. & Richardson, M. J. What would be Usain Bolt's 100-meter sprint world record without Tyson Gay? Unintentional interpersonal synchronization between the two sprinters. *J. Exp. Psychol. Hum. Percept. Perform., 41(1)*:36-41, 2015.

Zaciorski, V. M. & Kramer, V. J. *Science and practice of sport training.* Beograd, Naucna Knjiga, 2009.

Corresponding author:
Dragan Doder, PhD, Full Research Professor
Department for Sport and Sports Medicine of Province
21000 Novi Sad
Masarikova 25
SERBIA

E-mail: dodersport@yahoo.com