MOTOR ENTROPY INFLUENCE ON SPORT RESULTS: USAIN BOLT'S RECORD-BREAKING RACE EXAMPLE

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The purpose of this study was to estimate Usain Bolt's motor entropy and to calculate its effect on athletic performance. The paper analyzes momentary velocity for Usain Bolt in the men's 100 m final at the 2009 IAAF World Championships. Applied to results in cyclic sports, motor entropy depends on the ability to reproduce the most effective running stride. Any variations negatively affect to sports performance and lead to increasing of entropy. We identified Shannon entropy for peaks (4.5 bit) and troughs (2.9 bit) of intracyclic velocity. Numerical simulation of momentary velocity with zero entropy shows that Usain Bolt's time could be 9.42 s instead 9.58 s. Zero entropy means absolute body control without technique inaccuracies and full realization of the motor potential. Motor entropy is one of the factors that determine athletic performance.

KEYWORDS: world record, entropy, motor control.

INTRODUCTION: Every step of human's life is unique and unrepeatable. N. Bernstein (1967) studied this phenomenon and formulated the principle of motion control "iterations without repetitions". The problem is lack of knowledge how the movement uncertainty affects sports performance. High of stereotypical movement uncertainty means the high entropy (Wiener, 1985). Elite world sprinters are unique humans for the entropy study. They have perfect motor apparatus and outstanding technique. Investigators of sports records are interested physiological limits of human capabilities (Hill, 1925), trends and predictions of sports results (Lippi et al., 2008; Nevill & Whyte, 2005). The entropy and variability indicators have used for study and describe physiological processes (Boregowda et al., 2016) and human movements (Leverick et al., 2014). We assume that entropy and variation indicators can allow to accurately assess the athletes' potential and to predict they results. The broader question of research is demonstrating that entropy as measure of chaos can characterize the quality of human motor control. The study of these indicators should be based on the analysis of data obtained by precise biomechanical control tools. The purpose of this study was to estimate Usain Bolt's motor entropy and to calculate its effect on athletic performance.

METHODS: The research is based on Usain Bolt momentary velocity analysis in men's 100 m final at the 2009 IAAF World Championships in Berlin. This data is unique because the new world record is set (9.58 sec). The intracyclic velocity charts are taken from the IAAF official website (Graubner & Nixdorf, 2011). Momentary velocity data is obtained by laser measurement system. The data of exactly reflects the uniqueness of the movement and allows estimating the motor entropy. We don't have the original numerical values of the momentary velocity, so we quantized the existing graph. The quantization included mapping, scaling and interpolation points. It allows us to describe all features of the original curve in high degree of similarity. Based on this data the Usain Bolt momentary velocity graph is reconstructed (Figure1). The intracyclic velocity graph is compared with the race video in slow-motion mode to determine the left and right running strides.
The graph shows that each oscillation corresponds to one running stride. The maximum peaks and the minimum troughs of the intracyclical speed have been chosen as characteristics that objectively reflect entropy and variation. We use the distance segment from 30 to 80 meters to perform analysis because we can expect very similar repetition of strides. Of course, other kinematic or dynamic characteristics could be used as an entropy indicator.

The resulting sample has been analyzed using descriptive analysis and analysis of variance (ANOVA). We also have used F-test to understand statistical reliability of the difference between left and right strides (Table 1).
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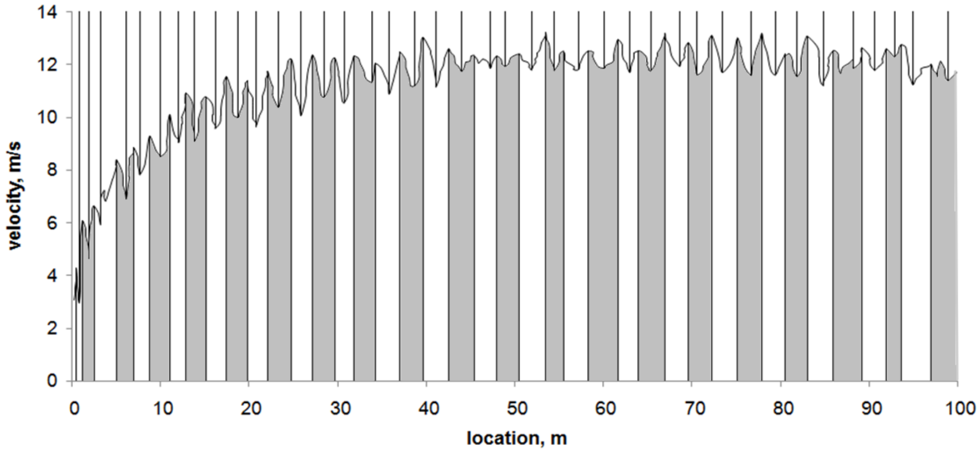

Figure 1: Momentary velocity vs location for Usain Bolt in the men's 100m final at the 2009 IAAF World Championships in Athletics (quantized).

The Shannon formula was used to calculate entropy (Shannon, 1948). The measurement accuracy was Δt =0,1 m/s.

$$H_x = -\sum_{n=1}^{N} p_n \log_2 \mathrm{p_n}$$

where p_n – is the probability; N – number of possible positions.

RESULTS: The functional asymmetry of the left and right strides should be considered as systematic variability. The difference of right or left strides inside groups is randomized variability which associated with the quality of coordination: the accuracy of nerve impulses and muscles corrections.
Total variation consists of intra-group variation and inter-group variation (Table 1), so it is possible to define the shares of systematical and randomized variability (Table 2).

Table 1: Results of the Usain Bolt's intracyclic velocity analysis

	n	$\bar{V}$, *m/s*	intra-group variation[1]	inter-group variation[2]	total variation[3]	F-test α=0,05[4]
peaks						
right	10	12.71±0.34	1.06	0.02	2.33	0.15
left	9	12.64±0.35	1.25			
troughs						
right	10	11,50±0,47	2.00	0.09	2.56	0.62
left	9	11,65±0,24	0.47			

[1] intra-group variation (the intra-group sum of the squared deviation): $SS_{intra} = \sum\sum(V_{ij} - \bar{V_i})^2$.
[2] inter-group variation (the intergroup sum of the squared deviation): $SS_{inter} = \sum(V_i - \bar{V})^2$.
[3] total variation (the total sum of the squared deviation): $SS_{total} = \sum\sum(V_{ij} - \bar{V})^2$.
[4] F-test crucial value = 4.45.

Table 2: Systematic and randomized variability in Usain Bolt's momentary velocity

	systematic variability (%)	randomized variability, %
peaks	0.02 (0.86)	2.31 (99.14)
troughs	0.09 (3.56)	2.47 (96.43)

Thus, significant share in Usain Bolt's movement uncertainty is randomized variability. The entropy of peaks and troughs was calculated based on the distribution of values (Figure 2). For peak case N=13 (intervals), p_n = frequency (n) /N.

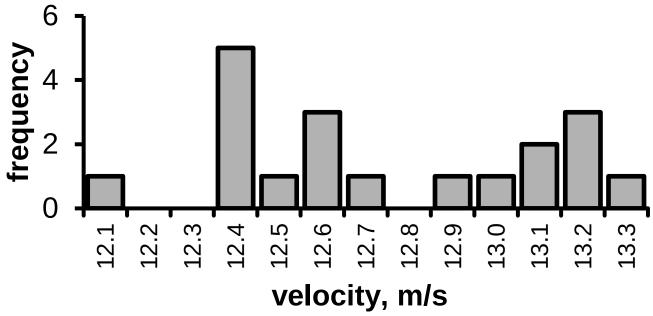

Figure 2: Distribution of intracyclic velocity peaks.

The entropy of the peaks was Hp=4.46 bits, the troughs Ht= 2.90 bits.

DISCUSSION. Analyzing simplistic walking robot allows us easily to make sure that all its steps are equal in both kinematic and dynamic parameters. In this case, both the systematic and randomized variability tend to zero. All human movements are unique due to special body control system. The question of how the minimization of motor entropy would affect to the Usain Bolt's result is particular interest.

To calculate the distance time, Figure 1 has been transferred from Cartesian system "momentary velocity vs location" to Cartesian system "momentary velocity vs time". Each elementary section of the distance (dS) is divided by elementary momentum velocity (dV), thereby $dt = \frac{dS}{sV}$. We have selected a small enough finite element 0.1 meter to reduce the error. Mathematical interpolation is applied to construct an array with given discreteness. In our calculations, we have taken into account the Usain Bolt's reaction time 0.146 s. Calculated race time is 9.472 s. The real time, as known, is 9.58 s. Thus, the difference was 0.108 sec or 1.1% of the distance time due to imperfection of the measurement system and errors associated with quantization. Based on these values a correction coefficient k= 1.0114 has been added to the calculation of the model (zero entropy) race time.

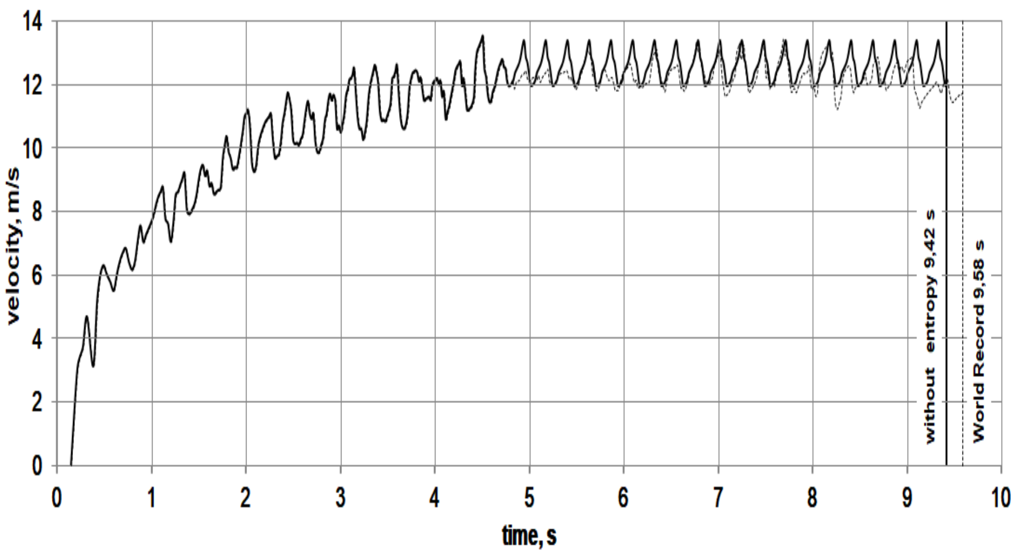

Figure 3: Usain Bolt's real and idealized intracyclic velocities (momentary velocity vs time).

We have selected the stride with the highest realization of the motor potential to simulate such race. This stride differs by the highest peak speed and shallow decline one. It is the stride # 32 (75-77 meter) when repulsion by the right leg. We have simulated the case of zero entropy from moment of reaching the maximum speed until finish. So, we introduced the assumption that after reaching the maximum speed, the athlete is able to maintain the speed and constant biomechanical characteristics to finish. All subsequent values of the intracyclic velocity have been replaced by the idealized stride # 32 values (Figure 3).
Finally, we have calculated the theoretical race time with zero entropy. It is 9.42 s. The time decline due to zero entropy in the model case was 0.16 s (Figure 3).
Motor entropy is one of the factors that determine athletic performance. Coaches and athletes in cyclical sports should pay attention not only to the velocity and strength perfection but also to take into account motor entropy and try to reduce it. This is the practical significance of the study.

CONCLUSION: The paper analyzes the curve of Usain Bolt's intracyclic velocity in the historical race in the men’s 100m final at the 2009 IAAF World Championships. Each stride of this race is unique and differs in kinematic characteristics. Using the Shannon formula the motor entropy of the peaks and troughs of the intracyclic velocity was determined, which was 4.46 and 2.90, respectively. The entropy is directly related to the variability of movements. The study revealed that more 95 % variation refers to random deviations and less 5% to systemic variation associated with motor asymmetry. Numerical simulation of the intracyclic velocity curve demonstrates that the result of Usain Bolt with zero entropy could be 9.42 s.

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