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Relations Between the World Record in Running at 100m and Altitude and Wind Speed

Relacije svjetskog rekorda u trčanju na 100m sa nadmorskom visinom i brzinom vjetra

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Abstract: *A sprint is a dynamic and explosive cyclic movement determined by an ability to accelerate, a size of maximum speed and an ability to maintain the speed in relation to an onset of fatigue, so many factors can affect a sprint result, whether they are of an internal nature - motivation, technique, readiness and fatigue, or external - wind direction and strength, altitude, temperature, texture and hardness of substrate. The goal of the research was to determine the connection between altitude and wind speed with the achieved results in the 100m running for men, which are categorized as world records (manually and electronically measured results) and to predict the results depending on altitude and wind speed, and to determine the best achieved times in years in which no world records were recorded and their connection with altitude and wind speed, and to determine the periods of stagnation of the results, in order to determine, after specifying those periods, whether the altitude of the cities where the records were achieved and the wind speed were possible causes of the stagnation measured during the achievement of the results, which would all help to create more optimal conditions for achieving a better result and setting a new record in the 100m running discipline. After all the analyses, that is, by observing the results of recognized world records measured manually and electronically, it can be concluded that the wind speed had a connection and prediction in the achievement of the world record in the period from 1912 to 1968 when the results were measured manually (if the wind increased by 1 ms^{-1} the result improved by 0.08 sec), while the altitude value had a connection and prediction in the achievement of world records in the period from 1968 to 2009 when the results were recorded by electronic measurement (if the altitude increased by 1m the result improved by 0.00008 sec).*

Keywords: *altitude, sprint, wind speed, world record*

Sažetak: *Sprint je dinamično i eksplozivno ciklično kretanje određeno sposobnošću akceleracije, veličinom maksimalne brzine i sposobnosti da se održi brzina u odnosu na početak zamora, pa mnogi faktor mogu uticati na rezultat u sprintu bilo da su unutrašnjeg karaktera – motivacija, tehnika, spremnost i umor, ili spoljašnjeg – smjer i jačina vjetra, nadmorska visina, temperatura, tekstura i tvrdoća podloge. Cilj istraživanja bio je utvrditi povezanost nadmorske visine i brzine vjetra sa ostvarenim rezultatima u trčanju na 100m za muškarce koji su kategorisani kao svjetski rekordi (ručno i elektronski mjereni rezultati) i izvršiti predikciju rezultata u zavisnosti od nadmorske visine i brzine vjetra, te utvrditi najbolje ostvarena vremena u godinama u kojima nisu zabilježeni svjetski rekordi i njihovu povezanost sa nadmorskom visinom i brzinom vjetra, i utvrditi periode stagnacije rezultata, kako bi se nakon određivanja tih perioda utvrdilo da li su mogući uzroci stagnacije nadmorska visina gradova u kojima su rekordi postignuti i brzina vjetra izmjerena prilikom ostvarivanja rezultata, što bi sve pomoglo kreiranju optimalnijih uslova za ostvarivanje boljeg rezultata i postavljanje novog rekorda u disciplini trčanje na 100m. Nakon svih analiza, odnosno posmatranjem rezultata priznatih svjetskih rekorda mjerenih ručno i elektronski, može se zaključiti da je brzina vjetra imala povezanost i predikciju kod ostvarivanja svjetskog rekorda u periodu od 1912. do 1968. godine kada su rezultati mjereni ručno (ako se vjetar poveća za 1 ms^{-1} rezultat će se poboljšati za 0.08 s), dok je vrijednost nadmorske visine imala povezanost i predikciju u ostvarivanju svjetskih rekorda u period od 1968. do 2009. godine kada su rezultati bilježeni elektronskim mjerenjem (ukoliko se nadmorska visina poveća 1m rezultat će se poboljšati za 0.00008 s).*

Ključne reči: *sprint, svjetski rekord, nadmorska visina, brzina vjetra*

Introduction

Athletics is the main part of the program at the Olympic Games (Jotov, Perisic, Milosavljevic and Miletic, 2022), but also an important part of physical education programs at all levels of education (Stefanovic, 1992a). At the first Olympic Games, held in 776 BC, the only sprint discipline on the program was a race over one stage with a length of 192.27m (Ciric, 1996). Time measurement in athletics was made possible by the invention of George Graham, who in 1721 added a third hand to clocks which marked seconds, so at the beginning of the 19th century, time measurement began and a certain Berkeley's victory in 1803 on the 440-yard track was recorded in a time of 56.0 seconds (Stefanovic, 1992a). A parallel development of sports and technology enables a new asset of modern society, such as measuring time in different sports, as well as recording human capabilities that elite athletes strive for the most (a result that fascinates both competitors and the audience and represents a limit - a world record). In order for a performance to be recognized as a record, it must comply with specific regulations regarding a conduct of a discipline, a method of measuring results, dimensions and properties of a track, equipment used by an athlete and doping controls (IAAF, 2015). Measuring results and "breaking through" the limits of human capabilities are of great importance for the development of athletics (Perisic, Milosavljevic, Jotov and Rajkovic, 2022).

The 100m sprint is often an indicator of movement speed, and the world record holder is marked as the fastest man in the world (Stefanovic, 1992b). In 1968, Jim Haynes became the first man to run under ten seconds: his time of 9.9 was the last world record to be timed manually, and his 9.95, achieved during the Mexico Games, was the first world record timed electronically.[1] French biomechanics and sports researchers who studied human psychophysical abilities, believe that athletes in most athletic disciplines have "used up" as much as 99% of human potential, and in some as much as 99.7% (Perisic, 2011). In the period of 110 years (1912-2022), 67 world records were achieved, and Donald Lippincott's record from 1912 (10.6s) was improved by "only" one second and now stands at 9.58s (Usain Bolt). Improvement of results in the period 1968-2009 was 0.37 s which is an increase of 3.72%, and in the same period the world record for 200 m was revised six times from 19.83 s to 19.19 s which is 3.33 % (Krzysztof and Mero, 2013). In the sprint race for men, at the World Championships in Berlin in 2009, Usain Bolt, breaking two world records,

[1] 100 meter race — Wikipedia (wikipedia.org)

Uvod

Atletika je glavni dio programa na Olimpijskim igrama (Jotov, Perišić, Milosavljević i Miletić 2022), ali i važan dio programa fizičkog vaspitanja na svim nivoima obrazovanja (Stefanović,1992a). Na prvim Olimpijskim igrama, održanim 776. godine prije nove ere, jedina sprinterska disciplina na programu bila je trka na jedan stadijum dužine 192.27m (Ćirić, 1996). Mjerenje vremena u atletici omogućio je pronalazak Džordž Grejema koji je 1721. godine dodao treću iglu na satove koja je označavala sekunde, pa se početkom 19. vijeka počinje sa mjerenjem vremena gde se bilježi pobjeda izvjesnog Berklija 1803. godine na stazi od 440 jardi vremenom od 56.0 sekundi (Stefanović, 1992a). Paralelni razvoj sporta i tehnologije omogućava jednu novu tekovinu savremenog društva kao što je mjerenje vremena u različitim sportovima, kao i bilježenje ljudskih mogućnosti kojoj najviše teže elitni sportisti (rezultat koji fascinira i takmičare i publiku i predstavlja granicu - svjetski rekord). Da bi nastup bio priznat kao rekord, mora biti u skladu sa specifičnim propisima koji se tiču odvijanja discipline, metode mjerenja rezultata, dimenzija i svojstava staze, opreme koju sportista koristi i doping kontrole (IAAF, 2015). Mjerenje rezultata i „probijanje" granica ljudskih mogućnosti imaju veliki značaj za razvoj atletike (Perišić, Milosavljević, Jotov i Rajković 2022).

Sprint na 100 m često je pokazatelj za brzine kretanja, a svjetski rekorder je označavan kao najbrži čovek na svijetu (Stefanović, 1992b). Godine 1968. Džim Hejns je postao prvi čovjek koji je trčao ispod deset sekundi: njegovo vrijeme od 9.9s je posljednji svjetski rekord koji je ostvaren pomoću ručnog mjerenja vremena, a njegov rezultat od 9.95s, postignut tokom Meksičkih igara, predstavlja prvi svjetski rekord mjeren elektronskim putem. Francuski biomehaničari i istrživači sporta koji su proučavali ljudske psihofizičke sposobnosti, smatraju da su atletičari u većini atletskih disciplina „utrošili" čak 99% ljudskih mogućnosti, a u nekima i 99.7% (Perišić, 2011). U periodu od 110 godina (1912-2022) postignuto 67 svjetskih rekorda, a rekord Donalda Lipinkota iz 1912. (10.6s) poboljšan je za „samo" jednu sekundu i sada iznosi 9.58s (Jusein Bolt). Poboljšanje rezultata u periodu 1968-2009. godine iznosi 0.37 s što je povećanje od 3.72%, u istom razdoblju svjetski rekord na 200 m revidiran je šest puta sa 19.83 s na 19.19 s što iznosi 3.33 % (Krzysztof i Mero, 2013). U sprinterskom trčanju za muškarce, na Svjetskom prvenstvu u Berlinu 2009. godine, Jusein Bolt je, oborivši dva svjetska rekorda, na 100 i 200m pomjerio „granicu sno-

moved the "dream border" at 100m and 200m, which has not been broken to this day. Based on the analysis of thousands of sprint races between 1920 and 2007, biologist Mark Denn, from Stanford University in California, determined that the result of 9.48s is the ultimate limit in men's 100m sprint (Perisic, 2011). After the race in Beijing, Glenn Mills, Bolt's coach, stated that Bolt could have achieved a time of 9.52s if he had not started to rejoice before crossing the finish line and thus slowed down the speed of movement he achieved by the 60th meter of the race, and Bolt stated to the Belgian media that his goal was to lower the world record for 100m from the current 9.58 to 9.40 seconds and he believed that this was the ultimate limit, which could no longer be broken (Perisic, 2011).

A sprint is a dynamic and explosive cyclic movement determined by an ability to accelerate, a size of maximum speed and an ability to maintain the speed in relation to an onset of fatigue, so many factors can affect a sprint result, whether they are of an internal nature - motivation, technique, readiness and fatigue, or external - wind direction and strength, altitude, temperature, texture and hardness of substrate (Nigg and Yeadon, 1987; Stafilidis and Arampatzis, 2007). At constant air pressure and temperature, air humidity shows little influence on the 100-meter race time, providing corrections below 0.01 s for the considered range, which is negligible, while corrections increase if the temperature varies at constant air humidity, but relatively little - 0.023 s (Mureika, 2006). Wind is one of the many forms of climatic conditions that can affect sports, and in athletics, wind aid is a benefit that an athlete receives during a race, which is recorded by a wind gauge (Zanca, 2019). Performance in the 100m sprint can be significantly aided by a strong tailwind, so the International Association of Athletics Federations (World athletics) has a limit of 2ms^{-1} for allowable tailwind when recognizing the 100m record, and experimental and statistical works on wind aid in sprinting suggest that a tailwind of +2.0 ms^{-1} reduces the result in a 10 s 100 m sprint by about 0.10 s (Mureika, 2001). At sea level, the corrections differ by about 0.02s, but increase for stronger winds and higher altitudes, while the difference between the maximum and minimum considered corrections is greater than 0.5s, implying that times running with "equal" winds can, in fact, significantly differentiate (Mureika, 2003). A high altitude competition venue is believed to improve sprint performance by reducing air density, which reduces the aerodynamic drag force acting on the athlete and thus allows the athlete to achieve a higher top speed (Ward-

va", koja do danas nije pomjerena. Na osnovu analize hiljada sprinterskih trka između 1920. i 2007. godine, biolog Mark Den, sa Univerziteta Stenford u Kaliforniji, utvrdio je da je rezultat 9.48s, krajnja granica u sprintu za muškarce na 100m (Perišić, 2011). Poslije trke u Pekingu, Glen Mils, Boltov trener, je izjavio da je Bolt mogao da ostvari vreme od 9.52s da nije počeo da se raduje prije polaska kroz cilj i tako usporio brzinu kretanja koju je ostvario do 60-tog metra trke, a Bolt je izjavio za belgijske medije da mu je cilj da svetski rekord na 100m spusti sa sadašnjih 9.58 na 9.40 sekundi i verovao je da je to krajnja granica, koja više neće moći da bude oborena (Perišić, 2011).

Sprint je dinamično i eksplozivno ciklično kretanje određeno sposobnošću akceleracije, veličinom maksimalne brzine i sposobnosti da se održi brzina u odnosu na početak zamora, pa mnogi faktor mogu uticati na rezultat u sprintu bilo da su unutrašnjeg karaktera – motivacija, tehnika, spremnost i umor, ili spoljašnjeg – smjer i jačina vjetra, nadmorska visina, temperatura, tekstura i tvrdoća podloge (Nigg i Yeadon, 1987; Stafilidis i Arampatzis, 2007). Pri konstantnom vazdušnom pritisku i temperaturi, vlažnost vazduha pokazuje mali uticaj na vrijeme trke na 100 metara, dajući korekcije ispod 0.01 s za razmatrani raspon što je zanemarivo, dok korekcije rastu ako temperatura varira pri konstantnoj vlažnosti vazduha ali relativno malo – 0.023 s (Mureika, 2006). Vjetar je jedan od mnogih oblika klimatskih uslova koji mogu uticati na sport, a u atletici, pomoć vjetra je dobrobit koju sportista dobija tokom trke, što bilježi mjerač vjetra (Zanca, 2019). Izvedba u sprintu na 100 metara može biti značajno potpomognuta jakim pratećim vjetrom, tako da Međunarodna asocijacija atletskih federacija (World athletics) ima ograničenje od 2 ms^{-1} za dozvoljeni pomoćni vjetar pri priznavanju rekorda na 100 metara a eksperimentalni i statistički radovi o pomoći vjetra u sprintu sugerišu da zadnji vjetar od +2.0 ms^{-1} smanjuje rezultat u sprintu od 10 s na 100 m za oko 0.10 s (Mureika, 2001). Na nivou mora, korekcije se razlikuju za oko 0.02s, ali se povećavaju za jači vjetar i veće nadmorske visine, dok je razlika između maksimalne i minimalne razmatrane korekcije veća od 0.5 s što implicira da se vremena koja se odvijaju sa „jednakim" vjetrom mogu, u stvari, značajno razlikovati (Mureika, 2003). Vjeruje se da mjesto za takmičenje na velikim nadmorskim visinama poboljšava performanse sprinta kroz smanjenje gustine zraka, što smanjuje aerodinamičku silu otpora koja deluje na sportistu i time omogućava sportisti da postigne veću maksimalnu brzinu (Ward-Smith, 1984). World athletics smatra „trčanje

Smith, 1984). World athletics considers "minimum altitude-assisted running" to be 1000 m above sea level and there is no limit to the altitude of the competition venue, although there is empirical evidence that sprint performance is significantly aided by higher altitude (Hollings, Hopkins & Hume, 2012; Matthews, 2015). Advantages that competitors achieve at high altitudes are diverse, which was confirmed by research conducted in Mexico City that showed that reduced wind resistance and the resistance of competitors' bodies in thin air enabled athletes to move more efficiently (Zanca, 2019). A wind of +1.8 ms^{-1} in Mexico City (2250 m) would give an advantage of about 0.29 s (Mureika, 2003). Ward-Smith (1984) found that men's 100m sprint performances at the 1968 Mexico City Olympics improved by 0.17s compared to performances at other Olympic Games, and Behncke (1997) calculated that performance improved by 0.17s. for men and 0.18s for women, but the accuracy of the results is questionable because the research did not correct race times for wind effects, used a mix of manual and electronic times, and Behncke did not take into account historical performance trends (Linthorne, 2016).

The goal of the research was to determine the connection between altitude and wind speed with the achieved results in the 100m running for men, which are categorized as world records (manually and electronically measured results) and to predict the results depending on altitude and wind speed, and to determine the best achieved times in years in which no world records were recorded and their connection with altitude and wind speed, and to determine the periods of stagnation of the results, in order to determine, after specifying those periods, whether the altitude of the cities where the records were achieved and the wind speed were possible causes of the stagnation measured during the achievement of the results, which would all help to create more optimal conditions for achieving a better result and setting a new record in the 100m running discipline.

Materials and Methods

In the research, methods of theoretical analysis were used, which was aimed at explaining the results achieved within the framework of achieving world record results in the men's 100m and the best running results in periods of stagnation in the achievement of world records on the same leg. Then, a descriptive method was used, which aimed to collect results from databases (https://worldathletics.org/records/all-time-toplists/sprints/100-metres/outdoor/men/senior) and to describe and explain connections between obtained results, as well as their rela-

uz pomoć minimalne visine" na nadmorskoj visini od 1000 m i ne postoji ograničenje za nadmorsku visinu mjesta takmičenja, iako postoje empirijski dokazi da su sprinterske performanse značajno potpomognute većom nadmorskom visinom (Hollings, Hopkins i Hume, 2012**;** Matthews, 2015)**.** Prednosti koje takmičari ostvaruju na velikim nadmorskim visinama raznoliki su, što je potvrđeno istraživanjem provedenim u Mexico Cityju koje je pokazalo da su smanjeni otpor vjetra i otpor tijela takmičara u razređenom vazduhu omogućili efikasnije kretanje sportista (Zanca, 2019). Vjetar od +1.8 ms^{-1} u Meksiko Sitiju (2250 m) bi dao prednost od oko 0.29 s (Mureika, 2003). Ward-Smith (1984) je otkrio da su muški sprinterski nastupi na 100 metara na Olimpijskim igrama u Meksiko Sitiju 1968. poboljšani za 0.17s u odnosu na nastupe na drugim Olimpijskim igrama, a Behncke (1997) je izračunao da su performanse poboljšane za 0.17s za muškarce i 0.18s za žene, ali je tačnost rezultata upitna jer istraživanja nisu korigovale vrijeme trke zbog uticaja vjetra, koristile su mješavinu ručnih i elektronskih vremena, a Behncke nije uzeo u obzir istorijski trend u performansama (Linthorne, 2016).

Cilj istraživanja bio je utvrditi povezanost nadmorske visine i brzine vjetra sa ostvarenim rezultatima u trčanju na 100m za muškarce koji su kategorisani kao svjetski rekordi (ručno i elektronski mjereni rezultati) i izvršiti predikciju rezultata u zavisnosti od nadmorske visine i brzine vjetra, te utvrditi najbolje ostvarena vremena u godinama u kojima nisu zabilježeni svjetski rekordi i njihovu povezanost sa nadmorskom visinom i brzinom vjetra, i utvrditi periode stagnacije rezultata, kako bi se nakon određivanja tih perioda utvrdilo da li su mogući uzroci stagnacije nadmorska visina gradova u kojima su rekordi postignuti i brzina vjetra izmjerena prilikom ostvarivanja rezultata, što bi sve pomoglo kreiranju optimalnijih uslova za ostvarivanje boljeg rezultata i postavljanje novog rekorda u disciplini trčanje na100m.

Metodologija

U istraživanju su korištene metode teorijske analize koja je bila usmerena na objašnjavanje rezultata postignutih u okviru ostvarivanja rezultata svjetskih rekorda na 100m muškarci i najboljih istrčanih rezultata u periodima stagnacije ostvarivanja svjetskih rekorda na istoj dionici. Zatim, je korištena deskriptivna metoda, koja je imala je za cilj prikupljanje rezulata iz baza podataka (https://worldathletics.org/records/all-time-toplists/sprints/100-metres/outdoor/men/senior) i da opiše i objasni veze između dobijenih rezultata, kao i njihove odno-

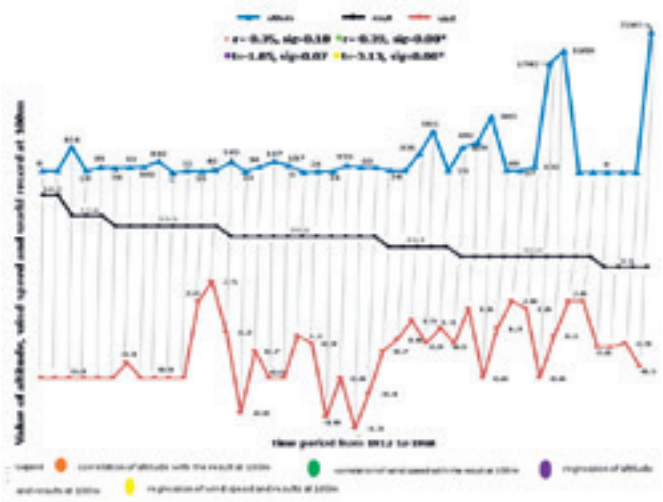
tionships. In this research, the results of the 100m world records measured by hand (43 results), the results of the 100m world records measured by electronic measurement (15 results) and the best results obtained during the stagnation period of achieving world records (the period from 1969 to 1982 - 15 results; the period from 1984 to 1987 - 4 results; the period from 2000 to 2004 - 5 results and the period from 2010 to 2023 - 14 results) were analyzed. The criterion variables in this research were the values of altitude (NV) and wind speed (VV) in the 100m races, while the predictor variable in this research was the results achieved in the 100m races. Statistical data processing was performed with the statistical program SPSS (version 20.0), and descriptive statistics, correlation analysis (linear relationship between two variables) and regression analysis (prediction of a variable (predictor) variable based on several independent (criterion) variables were performed.

Results

Table 1. *Descriptive statistics of manual measurement of world records at 100m*

	N	*M*	*S.d*
ALTITUDE / NV	43	257.81	51.45
WIND / VV	43	0.61	0.58
RES / REZ	43	10.16	0.17

Observing the average results of the achieved world records measured manually (table 1), it can be seen that the average world record was 10.16s, that the results were achieved at an average altitude of 257.81 m, and that the average wind speed was 0.61 ms^{-1}.



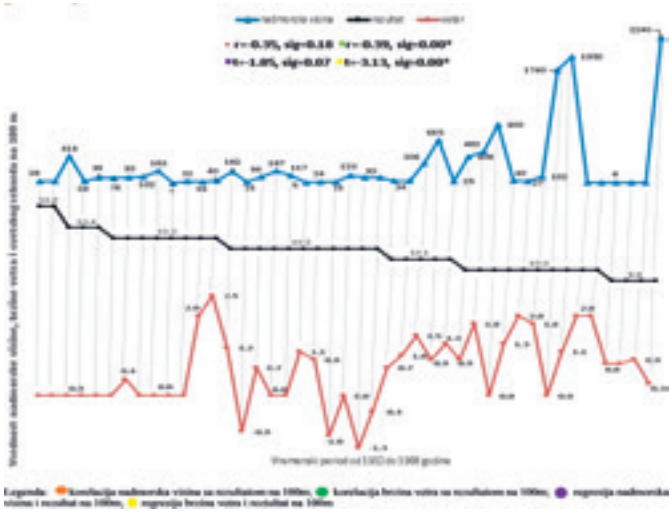
Graph 1. *Values of altitude, wind speed and world record at 100m in the period from 1912 to 1968 and their mutual relationship*

se. U ovom istraživanju su analizirani rezultati svjetskih rekorda na 100m mjerenih ručno (43 rezultata), rezultati svjetskih rekorda na 100m mjerenih elektronskim merenjem (15 rezultata) i najbolji rezultati istrčani u period stagnacije postizanja svjetskih rekorda (period od 1969. do 1982. - 15 rezultata; period od 1984. do 1987. - 4 rezultata; period od 2000. do 2004. - 5 rezultata i period od 2010. do 2023. - 14 rezultata). Kriterijske varijable u ovom istraživanju su bile vrednosti nadmorske visine (NV) i brzine vjetra (VV) na istrčanim trkama na 100m, dok je prediktorska varijabla u ovom istraživanju bila ostvareni rezultati u trkama na 100m. Statistička obrada podataka izvršena je statističkim programom SPSS (verzija 20.0), a provedene su deskriptivna statistika, korelaciona analiza (linearna veza između dvije promenljive) i regresiona analiza (predviđanje promenljive varijable (prediktorske) na osnovu više nezavisnih (kriterijskih) promenljivih).

Rezultati i diskusija

Tabela 1. *Deskriptivna statistika ručno merenje svjetski rekordi na 100m*

Posmatrajući prosečne rezultate ostvarenih svjetskih rekorda ručno mjerenih (tabela 1) uočava se da je prosječan svjetski rekord iznosio 10.16s, da su rezultati postignuti na prosječnoj nadmorskoj visini od 257.81 m, te da je prosječna brzina vjetra bila 0.61 ms^{-1}.



Grafikon 1. *Vrednosti nadmorske visine, brzine vjetra i svjetskog rekorda na 100m u periodu od 1912. do 1968. godine i njihov međusobni odnos*

By analyzing the correlation, i.e. the connection between the achieved results of the world records for the altitude where the values of the wind speed were run, the results shown in Graph 1 show that there is a statistically significant connection between the achieved results of the world records at 100m and the wind speed (r=-0.39. p=0.00*). It can be noticed that the negative sign correlation is shown, which means that if the wind speed is higher, the result is better and vice versa. The values of the results of the world records at 100m measured manually did not show a statistically significant relationship with the altitude. Graph 1 also shows the results of the prediction of world records at 100m based on altitude and wind speed. It is possible to predict the results based on the wind speed (p=0.00*), as shown by the correlation analysis. This means that the wind speed value is directly related to the 100m result values and is a significant factor that must be considered.

Analizom korelacije, odnosno povezanosti ostvarenih rezultata svjetskih rekorda nadmorske visine gdje su istrčani i vrednosti brzine vjetra rezultati prikazani u grafiku 1. govore da postoji statistički značajna povezanost ostvarenih rezultat svjetskih rekorda na 100m sa brzinom vjetra (r=-0.39. p=0.00*). Može se primjetiti da je pokazana korelacija negativnog predznaka što znači da ukoliko je brzina vjetra veća rezultat je bolji i obrnuto. Vrijednosti rezultata svjetskih rekorda na 100m mjerenih ručno nisu pokazali statistički značajnu povezanost sa nadmorskom visinom. Na grafiku 1. su, također, prikazani rezultati predikcije odnosno predviđanja rezultata svjetskih rekorda na 100m na osnovu nadmorske visine i brzine vjetra. Predviđanje rezultata moguće je ostvariti na osnovu brzine vjetra (p=0.00*) što je i pokazala korelaciona analiza. Ovo govori da je vrijednost brzina vjetra direktno povezana sa vrijednostima rezultata na 100m i značajan faktor koji se mora uzeti u obzir.

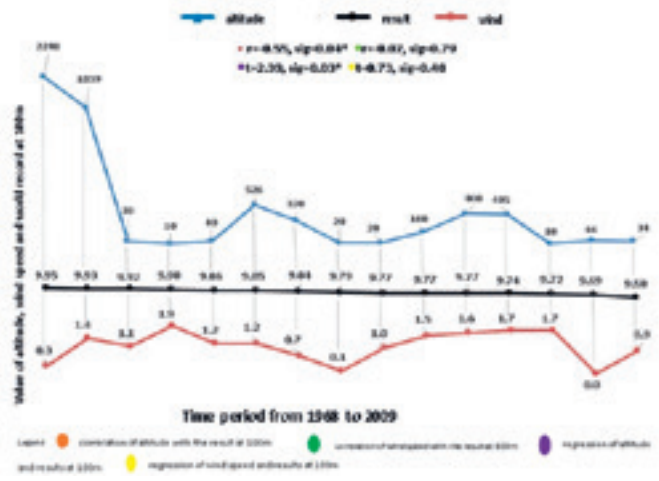
Table 2. *Descriptive statistics of electronical measurement of world records at 100m*

	N	*M*	*S.d*
ALTITUDE / NV	15	407.60	68.92
WIND / VV	15	1.08	0.59
RES / REZ	15	9.80	0.10

Tabela 2. *Deskriptivna statistika elektronsko merenje svjetski rekordi na 100m*

Observing the average results of achieved world records measured by electronic measurement in the period from 1968 to 2009 (table 2), it can be seen that in that period the average world record was 9.80s, that the results were achieved at an average altitude of 407.60 m, and that the average wind speed was 1.08 ms^{-1}.

Posmatrajući prosječne rezultate ostvarenih svjetskih rekorda mjerenih elektronskim mjerenjem u periodu od 1968. do 2009. godine (tabela 2) uočava se da je u tom razdoblju prosječan svjetski rekord iznosio 9.80s, da su rezultati postignuti na prosječnoj nadmorskoj visini od 407.60 m, te da je prosječna brzina vjetra bila 1.08 ms^{-1}.



Graph 2. *Values of altitude, wind speed and world record at 100m in the period from 1968 to 2009 and their mutual relationship*

Grafikon 2. *Vrijednosti nadmorske visine, brzine vjetra i svjetskog rekorda na 100m u periodu od 1968. do 2009. godine i njihov međusobni odnos*

Analyzing the correlation, i.e. the connection between the achieved results of world records and the altitude where they were run and the wind speed values, the results shown in Graph 2 show that there is a statistically significant correlation between the achieved results of world records at 100m and the altitude where they were run (r=0.55. p =0.04*). It can be noticed that the positive sign correlation is shown, which means that if the altitude is higher, the result is worse and vice versa. The values of the results of the world records at 100m measured by electronic measurement did not show a statistically significant connection with the wind speed that was used in those races.

The graph also shows the results of the prediction of world records at 100m based on altitude and wind speed. It is possible to predict the results based on the altitude (p=0.03) as shown by the correlation analysis, which means that the value of the altitude is directly related to the values of the results at 100m and is a significant factor that must be taken into account.

Analizom korelacije. odnosno povezanosti ostvarenih rezultata svetskih rekorda i nadmorske visine gdje su istrčani i vrijednosti brzine vjetra, rezultati prikazani u grafu 2. govore da postoji statistički značajna povezanost ostvarenih rezultat svjetskih rekorda na 100m sa nadmorskom visinom gdje su istrčani (r=0.55. p=0.04*). Može se primjetiti da je pokazana korelacija pozitivnog predznaka što govori da, ukoliko je nadmorska visina veća rezultat je lošiji i obrnuto. Vrednosti rezultata svjetskih rekorda na 100m mjerenih elektronskim mjerenje nisu pokazali statistički značajnu povezanost sa brzinom vjetra koja je izjerena na tim trkama. Na grafiku su, takođe, prikazani i rezultati predikcije odnosno predviđanja rezultata svjetskih rekorda na 100m na osnovu nadmorske visine i brzine vjetra. Predviđanje rezultata moguće je ostvariti na osnovu nadmorske visine (p=0.03) što je i pokazala korelaciona analiza, a to govori da je vrijednost nadmorske visine direktno povezana sa vrijednostima rezultata na 100m i značajan faktor koji se mora uzeti u obzir.

Table 3. *Descriptive statistics of electronic measurement of stagnation period from 1969 to 1982, from 1984 to 198, from 2000 to 2004 and from 2010 to 2023*

Tabela 3. *Deskriptivna statistika elektronsko mjerenje period stagnacije od 1969. do 1982, od 1984. do 1987, od 2000. do 2004. i od 2010. do 2023. godine*

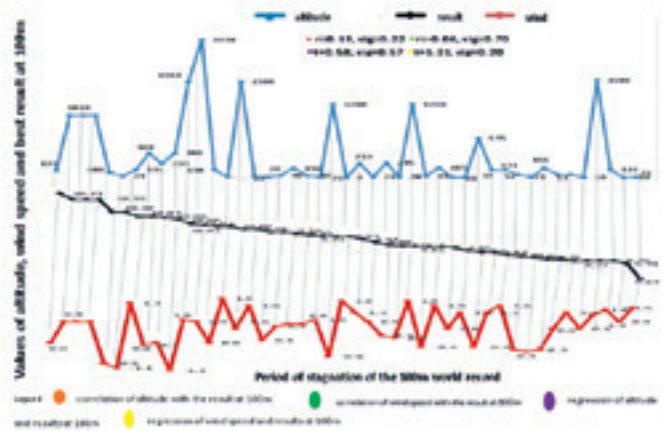
Period	ALTITUDE / NV			WIND / VV			RES / REZ		
	N	M	S.d	N	M	S.d	N	M	S.d
1969-2023*	45	336,41	54,77	45	0,66	0,21	45	9,91	0,13
1969-1982	15	613.92	73.58	15	0.21	0.08	15	10.06	0.07
1984-1987	4	56.00	6.67	4	1.10	0.34	4	9.95	0.02
2000-2004	5	145.60	27.93	5	0.58	0.37	5	9.87	0.04
2010-2023	14	181.64	40.83	14	0.87	0.72	14	9.77	0.05

**In the period from 1969 to 2023, there were also periods of stagnation lasting one or two years (1989-1990, 1992-1993, 1995, 1998-1999), a total of 7 results, which were not taken into consideration in individual analyzes because statistical analyzes do not recognize such a small sample, but are taken into consideration in the overall analysis.*

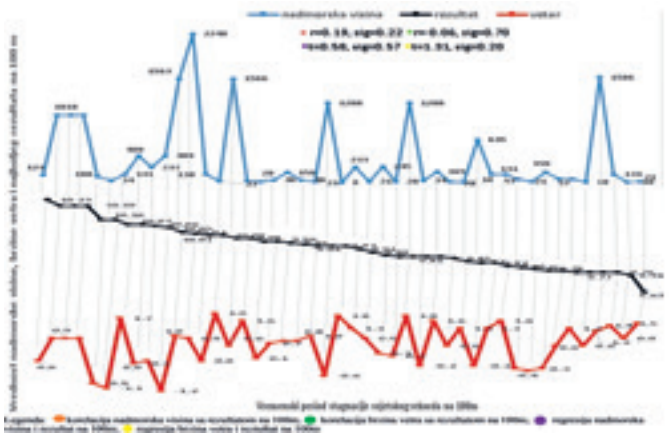
**U periodu od 1969 do 2023 bilo je i perioda stagnacije u trajanju od jednu ili dvije godine (1989-1990, 1992-1993, 1995, 1998-1999), ukupno 7 rezultata, koji nisu uzeti u razmatranje u pojedinačnim analizama jer statističke analize ne prepoznaju tako malobrojan uzorak, ali su uzeti u razmatranje u ukupnoj analizi.*

Looking at all the results (table 3) in the years when no world records were achieved at 100m (1969-2023), it can be seen that the average result is 9.91s, the average altitude is 336.41m, and the average wind speed is 0.66 ms^{-1}. Observing the average results of achieved world records by periods of stagnation (table 3), it can be seen that the best average result was in the period 2010-2023 and the worst in the period 1969-1982, that the highest average altitude was in the period 1969-1982, and the lowest in the period 1984-1987, and that the highest average wind speed was in the period 1984-1987 and the lowest in the period 1969-1982.

Posmatrajući sve rezultate (tabela 3) u godinama kada nisu postignuti svjetski rekordi na 100m (1969-2023) uočava se da je prosječan rezultat 9.91s, prosječna nadmorska visina 336.41 m, a prosječna brzina vetra 0.66 ms^{-1}. Posmatrajući prosječne rezultate ostvarenih svjetskih rekorda po periodima stagnacije (tabela 3) uočava se da je najbolji prosječan rezultat bio u periodu 2010-2023 a najlošiji u periodu 1969-1982, da je najveća prosječna nadmorska visina bila u periodu od 1969-1982, a najmanja u periodu 1984-1987, te da je najveća prosječna brzina vjetra bila u periodu 1984-1987 a najmanja u periodu 1969-1982.



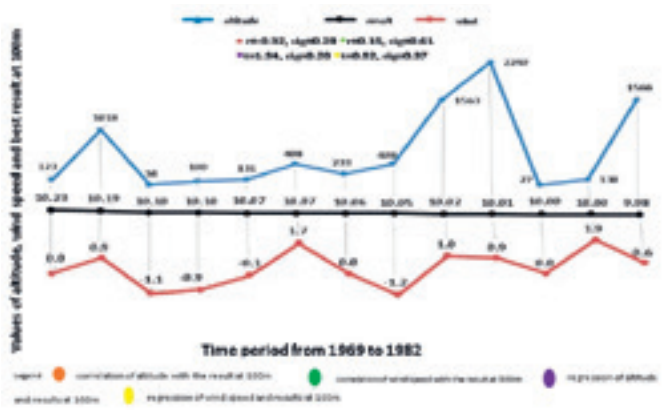
Graph 3. *Values of altitude, wind speed and the best result at 100m in the period since stagnation in total and their mutual relationship*



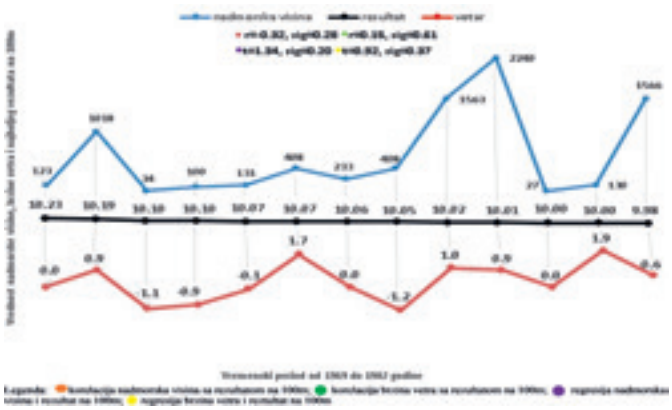
Grafikon 3. *Vrijednosti nadmorske visine, brzine vjetra i najboljeg rezultata na 100m u periodu od stagnacije ukupno i njihov međusobni odnos*

Analyzing the correlation, that is, the prediction of all results based on the values of altitude and wind speed in the period 1969-2023, no statistically significant correlations and predictions of results with the values of altitude and wind speed were observed (Graph 3).

Analiziranjem povezanosti, odnosno predikcije svih rezultata na osnovu vrednosti nadmorske visine i brzine vjetra u period 1969-2023., nije primećena statistički značajna povezanosti i predikcije rezultata sa vrednostima nadmorske visine i brzine vjetra (graf 3).



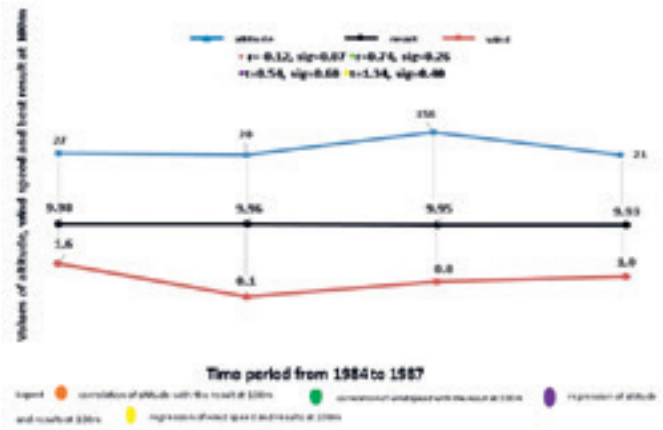
Graph 4. *Values of altitude, wind speed and best result at 100m in the period of stagnation from 1969 to 1982 and their mutual relationship*



Grafikon 4. *Vrednosti nadmorske visine, brzine vjetra i najboljeg rezultata na 100m u periodu od stagnacije 1969. do 1982. godine i njihov međusobni odnos*

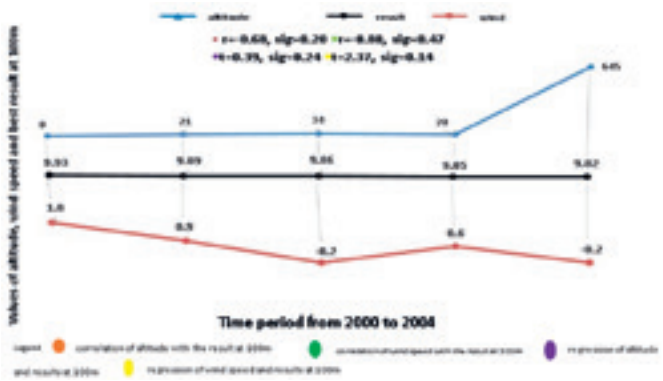
Observing the connection between the best results achieved at 100m in the period of stagnation (1969 to 1982) and the altitude where they were run and the wind speed values, the results shown in Graph 4 show that there is no statistically significant connection between the best results achieved in the period 1969-1982 with altitude where they were run (r=0.32, p=0.28) and wind speed (r=0.15, p=0.61). The graph also shows the results of the prediction of the best results at 100m in the period 1969-1982 based on altitude and wind speed. It is not possible to predict the results based on altitude (p=0.20), nor on the basis of wind speed (p=0.37).

Posmatrajući povezanosti ostvarenih najboljih rezultata na 100m u period stagnacije (1969 do 1982 godine) i nadmorske visine gdje su istrčani i vrednosti brzine vjetra, rezultati prikazani u grafikonu 4. govore da ne postoji statistički značajna povezanost ostvarenih najboljih rezultata u period 1969-1982. sa nadmorskom visinom gdje su istrčani (r=0.32. p=0.28) i brzinom vjetra (r=0.15. p=0.61). Na grafu su, takođe, prikazani i rezultati predikcije odnosno predviđanja najboljih rezultata na 100m u period 1969-1982. na osnovu nadmorske visine i brzine vjetra. Predviđanje rezultata nije moguće ostvariti na osnovu nadmorske visine (p=0.20), ni na osnovu vrednosti brzine vjetra (p=0.37).



Graph 5. *Values of altitude, wind speed and best result at 100m in the period of stagnation from 1984 to 1987 and their mutual relationship*

Observing the second period of stagnation of the world record at 100m (from 1984 to 1987), which is shown in Graph 5, no statistically significant correlation and prediction of the best results at 100m and altitude and wind speed were observed.



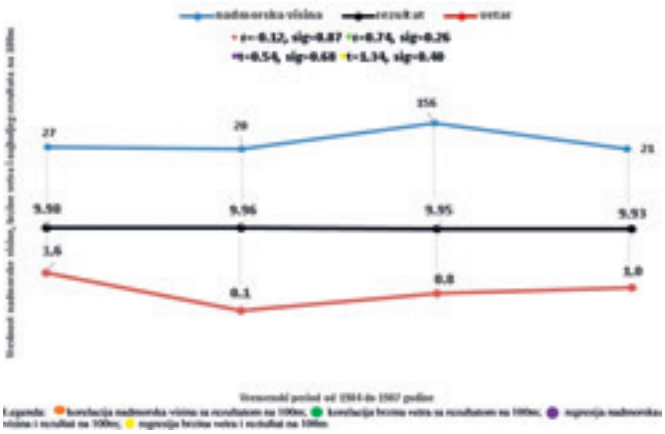
Graph 6. *Values of altitude, wind speed and best result at 100m in the period of stagnation from 2000 to 2004 and their mutual relationship*

Also, the third period of stagnation of the world record at 100m (from 2000 to 2004), which is shown in Graph 6, did not show a statistically significant correlation and prediction of the best results at 100m with altitude and wind speed.

In the fourth period of stagnation of the world record at 100m (from 2010 to 2023), no statistically significant correlation and prediction of the best results at 100m and the results of altitude and wind speed were observed (Graph 7).

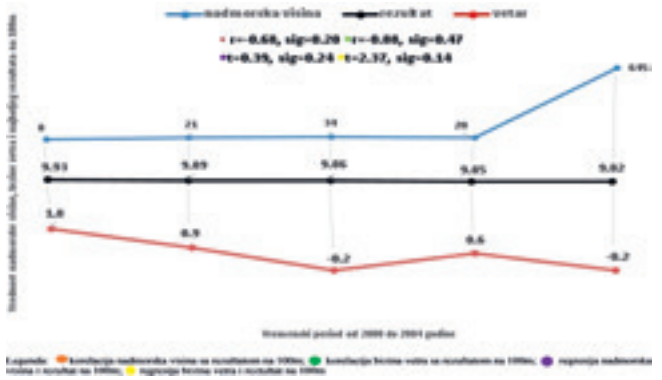
Discussion

After all the analyses, that is, by observing the results of recognized world records measured manually and electronically, it can be concluded that the wind speed had a



Grafikon 5. *Vrijednosti nadmorske visine, brzine vjetra i najboljeg rezultata na 100m u periodu od stagnacije 1984. do 1987. godine i njihov međusobni odnos*

Posmatrajući drugi period stagnacije svjetskog rekorda na 100m (od 1984. do 1987. godine) koji su prikazani u grafu 5. nije primećena statistički značajna korelacija i predikcija najboljih rezultata na 100m i nadmorske visine i brzine vjetra.



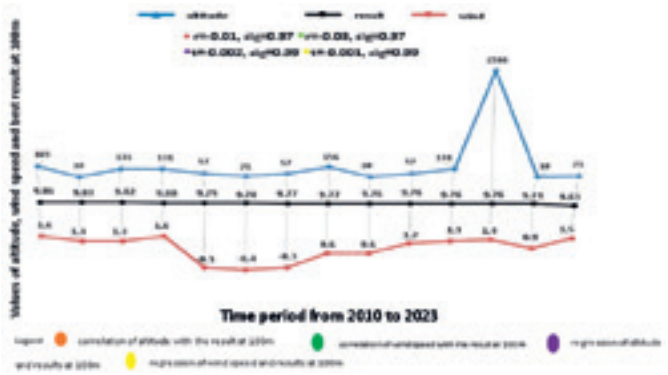
Grafikon 6. *Vrijednosti nadmorske visine, brzine vjetra i najboljeg rezultata na 100m u periodu od stagnacije 2000. do 2004. godine i njihov međusobni odnos*

Takođe, i treći period stagnacije svetskog rekorda na 100m (od 2000. do 2004. godine) koji je prikazan u grafu 6. nije pokazao statistički značajnu korelaciju i predikciju najboljih rezultata na 100m i nadmorske visine i brzine vjetra.

U četvrtom periodu stagnacije svjetskog rekorda na 100m (od 2010. do 2023. godine) nije primećena statistički značajna korelacija i predikcija najboljih rezultata na 100m i rezultata nadmorske visine i brzine vjetra (grafikon 7).

Diskusija

Nakon svih analiza, odnosno posmatranjem rezultata priznatih svjetskih rekorda mjerenih ručno i elektronski, može se zaključiti da je brzina vjetra imala pove-



Graph 7. *Values of altitude, wind speed and best result at 100m in the period of stagnation from 2010 to 2023 and their mutual relationship*

Grafikon 7. *Vrijednosti nadmorske visine, brzine vjetra i najboljeg rezultata na 100m u periodu od stagnacije 2010. do 2023. godine i njihov međusobni odnos*

connection and prediction in the achievement of the world record in the period from 1912 to 1968 when the results were measured manually (if the wind increased by 1 ms^{-1} the result would improve by 0.08 s), while the altitude value had a connection and prediction in the achievement of world records in the period from 1968 to 2009 when the results were recorded by electronic measurement (if the altitude increased by 1m the result would be improved by 0.00008 s). During the period of stagnation, the values of altitude and wind speed did not show a statistically significant connection or prediction, which might have been one of the reasons for this stagnation of the world record at 100m.

The development of the world record in athletics, and sports in general, has been influenced by several factors: enthusiasm of athletic (sports) experts (Bakov, 1961), evolution of technique (Stefanovic 1992b), development of athletic arenas (Skembler, 2007), improvement of sports equipment (Stefanovic, 2006), better training (Dik, 1980), pharmacological means of recovery (Dikic, 2007), financing (Mitrovic, Kantar, Rajkovic and Miletic, 2019), etc. The speed achieved in the sprint is determined by the processes of neuro-muscular regulation of movement, morphological characteristics, motor abilities and energy substrates (Mero, Komi and Gregor, 1992; Harland and Steele, 1997; Novacheck, 1998; Coh, Milanovic, Kampmiller, 2001; di Prampero , Fusi, Sepulcri, Morin, Belli and Antonutto, 2005), and is defined by step frequency and length (Delecluse, Ponnet and Diels, 1998; Brűggemann, Koszewski and Müller, 1999; Gajer, Thepaut-Mathieu & Lehenaff, 1999; Ferro, Rivera and Pagola, 2001), so the increase in step length is directly proportional to the decrease in step frequency (Mackala, 2007). Analyzing the progression of the world record at 100m, it can be concluded that in the period of 110 years (1912-2022) 67 world records were achieved, and Donald Lippincott's record from 1912 (10.6 s) was improved by "only" one second and now stands at 9.58 s (Ussain Bolt).

zanost i predikciju kod ostvarivanja svjetskog rekorda u periodu od 1912. do 1968. godine kada su rezultati mjereni ručno (ako se vjetar poveća za 1 ms^{-1} rezultat će se poboljšati za 0.08 sek), dok je vrednost nadmorske visine imala povezanost i predikciju u ostvarivanja svjetskih rekorda u period od 1968. do 2009. godine kada su rezultati bilježeni elektronskim mjerenjem (ukoliko se nadmorska visina poveća 1m rezultat će se poboljšati za 0.00008 sek). U period stagnacije vrijednosti nadmorske visine i brzine vjetra nisu pokazale statistički značajnu povezanost niti predikciju, što je možda jedan od razloga ove stagnacije svetskog rekorda na 100m.

Na razvoj svjetskog rekorda u atletici, i uopšte sportu, uticalo je više faktora: entuzijazam atletskih (sportskih) stručnjaka (Bakov, 1961) evolucija tehnike (Stefanović, 1992b), razvoj atletskih borilišta (Skembler, 2007), unapređenje sportske opreme (Stefanović, 2006), kvalitetniji trening (Dik, 1980), farmakološka sredstva oporavka (Dikić, 2007), finansiranje (Mitrović, Kantar, Rajković i Miletić, 2019), itd. Brzina postignuta u sprintu uslovljena je procesima neuro-mišićne regulacije kretanja, morfološkim karakteristikama, motoričkim sposobnostima i energetskim supstratima (Mero, Komi I Gregor, 1992; Harland i Steele, 1997; Novacheck, 1998; Čoh, Milanović, Kampmiller, 2001; di Prampero, Fusi, Sepulcri, Morin, Belli i Antonutto, 2005), a definisana je učestalošću i dužinom koraka (Delecluse, Ponnet i Diels, 1998; Brűggemann, Koszewski i Müller, 1999; Gajer, Thepaut-Mathieu i Lehenaff, 1999; Ferro, Rivera i Pagola, 2001), pa je povećanje dužine koraka izravno proporcionalno smanjenju frekvencije koraka (Mackala, 2007). Analizirajući progresiju svjetskog rekorda na 100m, može se zaključiti da je u periodu od 110 godina (1912-2022) postignuto 67 svjetskih rekorda, a rekord Donalda Lipinkota iz 1912. (10.6s) poboljšan je za „samo" jednu sekundu i sada iznosi 9.58s (Jusein Bolt). Trideset jedan

Thirty-one sprinters achieved one world record each, six achieved two world records each, four achieved three world records each, and three achieved four world records each.

About 75% of the Earth's land surface is at an altitude of less than 1000 m above sea level (Stacey and Davis, 2008), as is the vast majority of athletic competitions (Matthews, 2015). Sprint and jumping records were achieved in places above 1000 m - "aided by altitude" (Matthews, 2015). An altitude of 1000 m provides an advantage equivalent to a tailwind of 2 ms^{-1} (0.10 s), so the altitude of a competition venue should be taken into account when recognizing record-breaking performances in the 100 m sprint (Linthorne, 2016) . In the period 2000-2009, based on the performance of 56 elite male sprinters at major competitions, it was determined that the results achieved at an altitude above 1000 m above sea level were 0.05 s faster than those achieved in places below 1000 m above sea level and that the effect of the tailwind of 2 ms^{-1} in back improves the result by 0.08 s (Hollings, Hopkins and Hume, 2012), which indicates that the result in Mexico City (2250 m) should be given a time advantage of about 0.10 s (Linthorne, 2016). The analyzes of this research are not in accordance with those claims, because it was established that the world records were set at an average altitude of 407.60m, which is lower than 1000m, which would be worth investigating from the physiological basis of the body's functioning during sprint running, because, obviously, there are many factors that can be related to the result.

Explanation of the stagnation of the progress of world record results in the periods 1969-1982, 1984-1987, 2000-2004 and 2010-2023 should also be sought in the values of other climatic and other parameters. Also, potential factors that could affect the result and were not considered are: a time of year when a competition was held, differences in the time in which a sound of a starting gun travels to athletes from a starting gun, differences in sports shoes and the stiffness of a track, differences between athletes in the frontal area, effects of differences in air temperature, barometric pressure and humidity on aerodynamic resistance experienced by an athlete (Mureika, 2006) and an effect of temperature on generation of muscle power (Linthorne, 2016), because a fair system for recognizing record performances requires precise quantitative information about the effects of environmental conditions so that limits could be placed on the permissible range of conditions (Linthorne, 2016).

One of the problems with wind measurement in sprint running was observed at 200m, where there is a lack of wind data for the first half of the 200m race, because an anemometer measures wind speed of the last 85m of the race, but the question also arises as to whether wind speeds are constant

sprinter postigao je po jedan svjetski rekord, šestorica po dva svjetski rekord, četvorica po tri svjetski rekord, a trojica po četiri svjetska rekorda.

Oko 75% Zemljine kopnene površine nalazi se na nadmorskoj visini manjoj od 1000 m (Stacey i Davis, 2008), kao i velika većina atletskih takmičenja (Matthews, 2015). Rekordni u sprintu i skakanju postignuti su u mjestima iznad 1000 m- „potpomognute nadmorskom visinom" (Matthews, 2015). Nadmorska visina od 1000 m pruža prednost koja je ekvivalentna pomoćnom vjetru od 2 ms^{-1} (0,10 s), pa nadmorsku visinu mjesta takmičenja treba uzeti u obzir pri prepoznavanju rekordnih performansi u sprintu na 100 metara (Linthorne, 2016). U periodu 2000-2009. godina na osnovu nastupa 56 elitnih muških sprintera na velikim takmičenjima utvrđeno je da su rezultati postignuti na nadmorskoj visini iznad 1000 m bili 0.05s brži od onih postignutih u mjestima ispod 1000 m nadmorske visine i da efekat vjetra u leđa od 2 ms^{-1} u leđa poboljšava rezultat za 0.08 s (Hollings, Hopkins i Hume, 2012), što ukazuje da bi rezultat u u Mexico Cityju (2250 m) trebalo dati vremensku prednost od oko 0,10 s (Linthorne, 2016). Analize ovog istraživanja nisu u skladu sa tim tvrdnjama, jer je ustanovljeno da su svjetski rekordi postavljeni na prosječnoj nadmorskoj visini od 407.60m što je niža nadmorska visina od 1000m, što bi bilo vrijedno istražiti i sa fiziološke osnove funkcionisanja tijela prilikom sprinterskog trčanja, jer je očigledno da je mnogo faktora koji mogu biti povezani sa rezultatom.

Objašnjenje stagnacije napretka rezultata svjetskih rekorda u periodima 1969-1982, 1984-1987, 2000-2004. i 2010-2023. godine, takođe, treba tražiti u vrijednostima drugih klimatskih i ostalih parametara. Takođe, potencijalni faktori koji bi mogli uticati na rezultat a nisu razamatrani su: doba godine kada je takmičenje održano, razlike u vremenu u kojem zvuk startnog pištolja putuje do sportista iz startnog pištolja, razlike u sportskoj obući i krutosti staze, razlike među sportistima u frontalnom području, efekte razlika u temperaturi zraka, barometarskom pritisku i vlažnosti na aerodinamički otpor koji doživljava sportista (Mureika, 2006) i uticaj temperature na stvaranje mišićne snage (Linthorne, 2016), jer pravedan sistem priznavanja rekordnih performansi zahtjeva precizne kvantitativne informacije o efektima uslova sredine kako bi se mogla postaviti ograničenja na dozvoljeni opseg uslova (Linthorne, 2016).

Jedan od problema kod mjerenja vjetra kod sprinterskog trčanja uočen je na 200m gdje nedostatak podataka o vjetru za prvu polovinu trke na 200 m, jer vetromjer mjeri brzinu vjetra zadnjih 85 m trke, ali se postavlja pitanje

in the stadium, which questions the data on wind speed and its connection with the achieved result in the 100 m race (Mureika, 2003). The 100-meter sprint is the only discipline in which there is a reliable wind correction curve (Linthorne, 1994). Linthorne (2000) believes that the anemometer reading can only be accurate within ±0.9ms^{-1}. For the 100m races at the Olympics between 1964 and 2012, about 94% had wind readings between -2 and +2ms-^{1}, and only 4% were not eligible for the record because the wind was greater than +2ms^{-1} (Linthorne, 2016). In the 100m sprint, a tailwind of 2ms^{-1} produces a time advantage of about 0.10-0.12s over no-wind performance (Linthorne, 1994).

Applying mathematical models to calculate the time advantage of performing a 100m sprint in Mexico City gives an improvement in results of 0.05s (Dapena and Feltner, 1987), 0.08s (Mureika, 2001) and 0.10s (Behncke, 1997), but in Ward-Smith (1999) it is suggested that the predictions of mathematical models for sprinting should take into account a change in aerodynamic drag at a forward angle of a sprinter's body, as this is expected to affect sprinter's ability to generate forward propulsive force (which is only known with an accuracy of approx. 20%). The analyzes of this research are not in accordance with those claims, because it was established that the electronically measured world records were set at an average wind speed of 1.08, where no connection was established, so it is not possible to predict the results, while the connection of the wind with the manually measured results of the world records was shown, whereby a prediction can be made that with a wind speed of 1 ms^{-1} an improvement of the results of 0.08s can be expected. This, however, refers to a manually measured world records, while it cannot be claimed for electronically measured results. All of this points to the need for more detailed analyzes of as many factors as possible that can be related to the result in the 100m sprint, and that, in addition to mathematical models, it is necessary to analyze as many real factors and systems in which an athlete achieves the result with his/her performance.

Conclusion

Recent events related to the breaking of world records in athletics (broken world record in 400m, shot put, and pole vault) indicate that the limit of human capabilities has not yet been reached. The assumption is that the limits of records in athletics will still be moved, but much more slowly than before. The results of the research showed that until now the longest time distance between breaking two world records was 8 years, and the valid world record was achieved in 2009, thirteen and a half years ago, which indicates the fact that the world re-

i da li su brzine vjetra konstantne na stadionu što dovodi u pitanje i podatke o brzini vjetra i njenoj povezanosti sa postignutim rezultatom i u trci na 100 m (Mureika, 2003). Sprint na 100 metara je jedina disciplina u kojoj postoji pouzdana kriva korekcije vjetra (Linthorne,1994). Linthorne (2000) smatra da očitanje mjerača vjetra može biti tačno samo unutar ±0.9ms^{-1}. Za trke na 100 metara na Olimpijskim igrama između 1964. i 2012. godine, oko 94% je imalo očitavanje vjetra između 2 i +2 ms^{-1}, a samo 4% nije bilo kvalifikovano za rekord jer je vjetar bio veći od +2 ms^{-1} (Linthorne, 2016). U sprintu na 100 m pomoćni vjetar od 2 ms^{-1} proizvodi vremensku prednost od oko 0,10-0,12 s u odnosu na učinak bez vjetra (Linthorne, 1994). Primjena matematičkih modela za izračunavanje vremenske prednosti izvođenja sprinta na 100 metara u Mexico Cityju daje poboljšanje rezultata od 0.05 s (Dapena i Feltner,1987), 0.08s (Mureika, 2001) i 0.10s (Behncke, 1997), ali Ward-Smith (1999) sugeriše se da predviđanja matematičkih modela za sprint teba da uzmu u obzir promjenu aerodinamičkog otpora na ugao nagiba tijela sprintera prema naprijed, jer se očekuje da to utiče na sposobnost sprintera da generiše propulzivnu silu prema naprijed (što je poznato samo s preciznošću od oko 20%). Analize ovog istraživanja nisu u skladu sa tim tvrdnjama, jer je ustanovljeno da su elektronski mjereni svjetski rekordi postavljeni pri prosječnoj brzini vjetra od 1.08 pri čemu nije utvrđena povezanost pa se ne može izvršiti ni predikcija rezultata, dok se pokazala povezanost vjetra sa ručno mjerenim rezultatima svjetskih rekorda pri čemu se može izvršiti predikcija da se sa brzinom vjetra od 1 ms^{-1} može očekivati poboljšanje rezultata od 0.08s. To se, ipak odnosi na ručno mjeren svjetski rekord dok se ne može tvrditi za elektronski mjerene rezultate. Sve to ukazuje na potrebu detaljnijih analiza što većeg broja faktora koji mogu biti povezani sa rezultatom u sprintu na 100m, te da, i pored matematičkih modela, treba analizirati što više realnih faktora i sistema u kojima sportista svojom performansom ostvaruje rezultat.

Zaključak

poslednji događaji koji se odnose na obaranje svjetskih rekorda u atletici (oboreni svetski rekord na 400m, bacanju kugle, i skoku motkom) ukazuju da se još nije došlo do granice ljudskih mogućnosti. Pretpostavka je da će se granice rekorda u atletici još pomjerati, ali mnogo sporije nego do sada. Rezultati istraživanja su pokazali da je do sada najveća vremenska distanca između obaranja dva svjetska rekorda bila 8 godina, a važeći svjetski rekord postignut je 2009, prije trinaest i po godina, što ukazuje na činjenicu da će se svjetski rekord sve ređe

cords will be achieved less and less often. The conclusion reached by the analysis of the exhaustion of the men's 100m sprint record, when processed at a more profound level, leads to the opposite interpretation, which is reflected in the change of sports rules or a greater tolerance for mechanical aids, aggressive interventions on the human body, and all possible other options that will help to continue breaking the record ie. a projection of a false image of man's dominance over God, because "the show must go on". As health represents a kind of dynamic homeostasis, the assumption is that the future superior system of exercise and health will neither consider nor seriously encourage the phenomenon of records at any level, except in the sphere of interest.

In order to improve the results in the 100m sprint, it is necessary to include as many experts of all profiles as possible, whose actions would provide answers to the functioning of the human body in different environments and more complex systems in which it should deliver its performance to the maximum extent possible, because the observation of parts of the system through the data known to the wider scientific public, cannot give precise answers or instructions for achieving better results, and therefore not for improving world records.

i ređe postizati. Zaključak donešen analizom o iscrpljivanju rekorda u sprintu na 100m za muškarce, kada se obradi na dubljem nivou, vodi do suprotnog tumačenja, koje se ogleda u izmjeni sportskih pravila ili do veće tolerancije na mehanička pomagala, agresivne intervencije na ljudskom tijelu, i sve moguće druge opcije koje će pomoći da se nastavi obaranje rekorda tj. projekcija lažne slike dominacije čoveka nad bogom, jer „show must go on". Kako zdravlje predstavlja svojevrsnu dinamičku homeostazu, pretpostavka je da budući superiorni sistem vježbanja i zdravlja uopšte neće ni razmatrati, ni podsticati ozbiljno fenomen rekorda na bilo kojem nivou, sem u sferi zanimljivosti.

Kako bi se rezultati u sprintu na 100m poboljšavali, potrebno je uključiti što veći broj stručnjaka svih profila čije bi djelovanje dalo odgovore na funkcionisanje ljudskog tijela u različitim sredinama i kompleksnijim sistemima u kojima treba da svoju performansu izvede maksimalnim mogućnostima, jer posmatranje dijelova sistema kroz, široj naučnoj javnosti poznate podatke, ne mogu dati precizne odgovore niti upute za ostvarivanje boljih rezulatata, a samim tim ni za poboljšanje svjetskih rekorda.

REFERENCE

Asafa Powell profile. Retrived from https://worldathletics.org/athletes/jamaica/asafa-powell-1420, on 25.03.2023

Bakov, J. (1961). *Kod nas postoji danas atletski život, piščevo izdanje*. Ruski Krstur. [in Serbian]

Behncke, H. (1997). Optimization models for the force and energy in competitive running. J *Journal of Mathematical Biology*, 35, 375–390. https://doi.org/10.1007/s002850050057

Brüggemann, G.P., Koszewski, D., & Müller, H. (1999). *Biomechanical Research Project Athens 1997, Final report*. Oxford, Meyer & Meyer Sport, pp. 12–41.

Carl Lewis. Retrived from www.usatf.org/athlete-bios/carl-lewis, on 10.03.2023

Čoh, M., Milanović, D., & Kampmiller, T. (2001). Morphologic and kinematic characteristics of elite sprinters. *Collegium Antrop*, *25*(2), 605–610. UDC 572.512:796.42

Ćirić, A. (1996). *Igre u Olimpiji*. Beograd, RS: Vreme knjige. [in Serbian]

Dapena, J. & Feltner, M.E. (1987). Effects of wind and altitude on the times of 100-meter sprint races. *Int. J. Sport Biomech*, 3, 6–39. https://doi.org/10.1123/ijsb.3.1.6

Delecluse, C. H., Ponnet, H., & Diels, R. (1998). Stride characteristics related to running velocity in maximal sprint running. Riehle, H.J., & Vieten, M.M. (Ed.), *Proceedings II of XVI International Symposium on Biomechanics in Sports*. (pp. 146–148). ISBS.

Dik, F. (1980). *Trening vrhunskih atletičara*. Beograd, RS: „Partizan" Novinska izdavačka propagandna radna organizacija Saveza za fizičku kulturu Jugoslavije. [in Serbian]

Dikić, N. (2007). *100 pitanja o dopingu*. Beograd, RS: SIA. [in Serbian]

Donald Quarrie. Retrived from https://olympics.com/en/athletes/donald-quarrie, on 27.02.2023

di Prampero, P. E., Fusi, S., Sepulcri, L., Morin, J. B., Belli, A., & Antonutto, G. (2005). Sprint running: a new energetic approach. *The Journal of experimental biology*, *208*(Pt 14), 2809–2816. https://doi.org/10.1242/jeb.01700

Ferro, A., Rivera, A., & Pagola I. (2001). *Biomechanical analysis of the 7thIAAF World Championships in Athletics – Seville 1999.* New Studies in Athletics, (1,2). 25–60.

Gajer, B., Thepaut-Mathieu, C., & Lehenaff, D. (1999). *Evolution of stride and amplitude during course of the 100 m event in athletics.* New Studies in Athletics, 3, 43–50.

Harland, M. J., & Steele, J. R. (1997). Biomechanics of the sprint start. *Sports medicine (Auckland, N.Z.), 23*(1), 11–20. https://doi.org/10.2165/00007256-199723010-00002

History of face timing. Retrived from https://timingsense.com/en/blog/history-of-race-timing/, on 15.03.2023

Hollings, S.C.; Hopkins, W.G., & Hume, P.A. (2012). Environmental and venue-related factors affecting the performance of elite male track athletes. *Eur. J. Sport Sci.,* 12, 201–206.

Hollings, S.C., Hopkins, W.G., & Hume, P.A. (2012). Environmental and venue-related factors affecting the performance of elite male track athletes.

Eur. J. Sport Sci., 12, 201–206. doi:10.1080/17461391.2011.552640
International Association of Athletic Federations (IAAF)., (2015). IAAF Competition Rules 2016–2017; *International Association of Athletic Federations: Monaco, Monaco*,; pp. 168–169; 269–279.
James Ray Hines. Retrived from https://olympics.com/en/athletes/james-ray-hines, on 12.03.2023
Jotov, N., Perišić, D., Milosavljević, V., & Miletić, V. (2022). Perspektiva razvoja atletskog programa kroz prizmu Olimpijskih igara. In Stanković, V., Lilić, Lj., Stojanović, T., Cicović, B., & Ilić, I. (Ed.), *Zbornik radova, 9. Međunar,odna naučna konferencija „Antropološki i teoantropološki pogled na fizičke aktivnosti od Konstantina Velikog do danas* (pp. 261-265). Kosovska Mitrovica*, RS:* Fakultet za sport i fizičko vaspitanje u Leposaviću, Univerzitet u Prištini. UDC: 796.42.032.2 [in Serbian]
Krzysztof, M., & Mero, A. (2013). A kinematics analysis of three best 100 m performances ever. *Journal of Human Kinetics*, 36, 149-60. doi: 10.2478/hukin-2013-0015. PMid: 23717364; PMcid: PMC3661886.
Linthorne, N. P. (1994). The Effect of Wind on 100-m Sprint Times. *Journal of Applied Biomechanics, 10*(2), 110–131. doi:10.1123/jab.10.2.110
Linthorne, N. P. (2016). Improvement in 100-m Sprint Performance at an Altitude of 2250 m. *Sports,* 4*,* 2-29. doi:10.3390/sports4020029
Linthorne, N.P. (2000). In The engineering of sport: research development and innovation. Subic, A.J. &. Haake, S.J. (Ed.). *Proceedings of the 3rd International Conference on The Engineering of Sport* (pp. 451)*.* Oxford., Edited by Blackwell Science.
Mackala, K. (2007). Optimisation of performance through kinematic analysis of the different phases of the 100 meters. *New Studies in Athletics, 22*(2), 7–16.
Matthews, P. (2015). *Athletics 2015: The International Track and Field Annual*. York, UK: Sports Books. pp. 255–256.
Mero, A., Komi, P.V., & Gregor, R.J. (1992). Biomechanics of sprint running. A review. *Sports Med.* 13, 376–392. Doi: 10.2165/00007256-199213060-00002; PMid: 1615256
Mitrović, D., Kantar, M., Rajković, Ž., & Miletić, V. (2019). Predlog kriterijuma za određivanje nadležnih Granskih sportskih saveza za sportske grane i oblasti sporta u Republici Srbiji. *Knjiga radova 1. Nacionalne naučne i stručne konferencije "Aktuelnosti u teoriji i praksi sporta, fizičkog vaspitanja i rekreacije"* (pp. 202-208). Beograd, RS: Fakultet sporta i fizičkog vaspitanja. UDK 796/799(497.11) [in Serbian]
Mureika, J. R. (2001). A realistic quasi-physical model of the 100 m dash. *Canadian Journal of Physics, 79*(4), 697-713. https://doi.org/10.1139/p01-031
Mureika, J. R. (2003). Modeling wind and altitude effects in the 200 m sprint. *Canadian Journal of Physics, 81*(7), *895–910.* doi:10.1139/p03-062
Mureika, J.R. (2006). The effects of temperature, humidity, and barometric pressure on short-sprint race times. *Can. J. Phys.,* 84, 311–324. https://doi.org/10.1139/p06-057
Nigg, B.M., & Yeadon, M.R (1987). Biomechanical aspects of playing surfaces. *J Sports Sci. 5*(2) 117-45. Doi: 10.1080/02640418708729771; PMid: 3326948
Novacheck, T. (1998). The biomechanics of running. *Gait & posture*, *7*(1), 77-95.
Outdoor men senior 100 meters. Retrived from https://worldathletics.org/records/all-time-toplists/sprints/100-metres/outdoor/men/senior, on 11.03.2023
Perišić, D. (2011). *Uticaj svetskog rekorda na razvoj atletike*. Doktorska disertacija, Beograd, Fakultet sporta i fizičkog vaspitanja. [in Serbian]
Perišić, D., Milosavljević V., Jotov N., & Rajković Ž. (2022). Fenomen svetskih rekorda u atletici. In Stanković, V., Lilić, Lj., Stojanović, T., Cicović, B., & Ilić, I. (Ed.), *Zbornik radova, 9. Međunar,odna naučna konferencija „Antropološki i teoantropološki pogled na fizičke aktivnosti od Konstantina Velikog do danas* (pp. 266-271). Kosovska Mitrovica*, RS:* Fakultet za sport i fizičko vaspitanje u Leposaviću, Univerzitet u Prištini. UDC: 796.42.092.2 796.092.2 [in Serbian]
Percy Williams. Retrived from www.britannica.com/biography/Percy-Williams, on 12.03.2023
Ralph-Metcalfe, biography. Retrived from https://www.britannica.com/biography/Ralph-Metcalfe on 13.03.2023
Skembler, G. (2007). *Sport i društvo, istorija moć i kultura*. Beograd, RS: CLIO. [in Serbian]
Stacey, F.D. & Davis, P.M. (2008). *Physics of the Earth, 4th ed.;* Cambridge University Press: Cambridge, UK: p. 123.
Stafilidis, S., & Arampatzis, A. (2007). Muscule-tendon unit mechanical and morfological properties and sprint performance. *J Sports Sci. 25*(9) 1035-46. Doi: 10.1080/02640410600951589; PMid: 17497405
Stefanović, Đ. (1992a). *Atletika 2, nastanak i razvoj atletskih disciplina*. Beograd, RS: Fakultet fizičke kulture Univerziteta u Beogradu. [in Serbian]
Stefanović, Đ. (1992b). *Atletika 1, Tehnika*. Beograd, RS: Fakultet fizičke kulture Univerziteta u Beogradu. [in Serbian]
Steve Williams frofile. Retrived fromhttps://worldathletics.org/athletes/united-states/steve-williams-14355979, on 12.03.2023
Stefanović, Đ. (2006). *Teorija i praksa sportskog treninga I deo, Gnosis*. Beograd, RS: Fakultet fizičke kulture Univerziteta u Beogradu. [in Serbian]
This day in history. Retrived from www.history.com/this-day-in-history/owens-wins-4th-gold-medal, on 10.03.2023
Thomas Edward (Eddie) Tolan III. Retrived fromhttps://michigansportshof.org/inductee/eddie-tolan/, on 09.03.2023
Usain Bolt. Retrived from https://usainbolt.com/athlete/, on 15.03.2023
Valery Borzov. Retrived from https://www.britannica.com/biography/Valery-Borzov, on 12.03.2023
Zanca, R. (2019). The evolution of world records at 100 meter dash and the dynamics of the factors that influenced the sprinters performance capacity. Conference: 5TH International Conference of Universitaria Consortium cluj-Napoca – 2019, At: Cluj-Napoca, Romania,1-10.
Ward-Smith, A.J. (1984). Air resistance and its influence on the biomechanics and energetics of sprinting at sea level and at altitude. *J. Biomechanics,* 17, 339–347. https://doi.org/10.1016/0021-9290(84)90028-9
Ward-Smith, A.J. (1999). New insights into the effect of wind assistance on sprinting performance. *J. Sports Sci.,*17, 325–334. Doi: 10.1080/026404199366037; PMid: 10373041

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