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# Analiza kinematyczna kroku z maksymalną prędkością w biegu na 60 m
# Analysis of step kinematics during maximum speed of 60 m sprint performance

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## Abstrakt
Celem badania była analiza zmiennych kinematycznych kroku biegowego (długość kroku, częstotliwość kroku, czas kontaktu z podłożem, czas lotu i prędkość kroku) wykonanego z maksymalną prędkością, podczas sprintu na 60 m z bloku startowego. Do badań zrekrutowano dwie grupy, po siedmiu sprinterów w każdej grupie: szybsi sprinterzy (najlepszy czas 100 m: 10,37 ± 0,04 s) i wolniejsi (najlepszy 100-mi czas: 10,71 ± 0,15 s). Dane do analizy kinematycznej zostały wyodrębniona z pierwszych dziewięciu kroków 20-metrowego odcinka (między 40-60 m) w biegu na 60 m, przy użyciu systemu pomiarowego Opto-Jump-Microgate (Opto Jump, Włochy). Można wyraźnie zauważyć, że średni czas fazy lotu, średnia częstotliwość i długość kroku wykazały znaczące różnice statystyczne między grupami. Nasz eksperyment nie wykazał istotnych zmian w czasie fazy podporowej i czasie fazy lotu każdego z kroków, w obu grupach sprinterów oraz wskazał na stosunkowo liniowy

przebieg od kroku drugiego do kroku ósmego. Prędkość wykonywania pojedynczego kroku u szybszych sprinterów wykazywała liniowy wzrost w krokach od pierwszego do dziewiątego, jednak nie zauważono żadnych zmian w długości kroku między krokiem czwartym a siódmym w porównaniu z wcześniejszymi krokami, trzecim i szóstym. Z kolei wolniejsi sprinterzy wykazywali bardziej wyraźniejsze zmiany w obu tych parametrach, co może wyjaśniać rozwijanie mniejszej prędkości biegowej w tej grupie sprinterów. Analiza uzyskanych wyników może mieć duże znaczenie dla trenerów. Aby osiągnąć wyższą wartość maksymalnej prędkości w biegach krótkich, warto zwrócić uwagę na optymalizacje interakcji pomiędzy poszczególnymi zmiennymi.

**Słowa kluczowe**: sprint, kinematyka, parametry kinematyczne kroku, interakcja

## Abstract

The purpose of this study was to examine the step kinematics variables (step length, step frequency, ground contact time, flight time, and step velocity) of maximum speed measured during 60 m sprint performance from starting block. Two groups of seven fast (best 100-m time: 10.37 ± 0.04 s) and seven sub-fast (best 100-m time: 10.71 ± 0.15 s) sprinters were recruited. Step kinematics were extracted from the first nine running steps of the 20-m sprint (between 40-60 m) of 60 m sprint performance form the block using the Opto-Jump–Microgate system (Opto Jump, Italy). It can be clearly seen that the average time of the flight phase, the frequency and length of the step showed significant statistical differences between the groups. Our experiment did not show significant changes in CT and FT in either group of sprinters and showed a relatively linear course from step two to step eight . The velocity of step execution in the fast sprinters showed a linear increase across steps one to nine however no changes in SL between step four and seven was noticed when compared with earlier steps three and six. In turn, the sub-fast sprinters showed more pronounced variation in SV and SL, which may explain the slower running velocity in this group of sprinters. Analysis of the obtained results may be of great importance for coaches. In order to reach a higher value of maximal sprinting speed the optimal interaction between each variables is noteworthy.

**Keywords: sprint, kinematics, kinematic parameters of the step, interaction**

## Introduction

The major determinants of 100 m sprint are strength (1-3), power output (4-8), and first of all the speed and technique (10-11) based on the kinematic evaluation of sprinting step characteristics (11-16). The above information may suggest that sprint performance can be improved only when the technical proficiency of sprinter is able improve running/sprinting velocity. Therefore the running velocity is a product of step length (SL) and step frequency (SF) (13, 17-18). SL and SF are seen as mutually interdependent variables in which an increase in SL results in a decrease in SF and vice versa (19, 17, 20-21). Both variables are determined most by anthropometric characteristics, level of motor abilities development and sprinting step movement regulation processes (22,9, 23).

Based on this preliminary analysis of literature, we can assume that the mutual relations between SL and SF are unique and directly attributable to each sprinter (24, 23, 21, 25). The literature also showed that the mutual relations between these two factors of running speed are not unambiguous. Are we sure that the change of one factor causes the change of the second one, and above all, which factor SL or SF plays a greater role in improving the result in sprinting. There are many discussions about whether sprinters benefit more from increased SL or SF. Despite these discrepancies, the practice indicates that there is a strong correlation between SL and SF. It also emphasizes that running at both the maximum and sub-maximal speeds assumes that these are important measures of results when evaluating the variation in the sprint technique (8, 26-27).

The purpose of this study was to examine the step kinematics variables (step length, step frequency, ground contact time, flight time, and step velocity) of maximum speed measured during 60 m sprint performance from starting block and how these spatial-temporal characteristics can influence sprint running. To better understand the outcome of the study, to the experiment was recruited different competitive level of sprinters.

## Material and Methods

Two healthy groups of seven fast (age: 24.71 ± 2.43 years, body mass: 74.43 ± 8.24 kg, height: 179.42 ± 3.91 cm, best 100-m time: 10.37 ± 0.04 s) and seven sub-fast (age: 18.71 ± 0.75 years, body mass: 73.28 ± 4.49 kg, height: 182.00 ± 5.35 cm, best 100-m time: 10.71 ± 0.15 s) sprinters were recruited to the experiment. Each participant was medically cleared to participate in the 60 m sprint test. No physiological or orthopedic or limitation or injury that could affect sprint performance was noticed. All participants had previous experience in training and competition before enrollment. Written consent from each participant was obtained after the protocol and procedures were explained in full. Parental consent was also obtained from those individuals under 18 years of age. Additionally, they were instructed to avoid any strenuous physical activity 24 hours prior to the 60 m sprint testing. The Ethics Committee of the University of Physical Education in Wroclaw approved the experiment.

The 60-m block start were performed on an indoor track integrated with the Brower Timing TC-System (Draper, Utah, USA). The photocells were positioned on the track at the start and finish according to the sprint distance (Mackala and Fostiak 2015). Two trials were executed and separated by 6 min. of rest. Upon reaching the 20 m mark where approximately maximum speed appear, the sprinter continued to sprint for exactly 40 m at their individual velocity. The 20-m of maximum speed that was taken for kinematic analysis took place between 40 and 60 m of 60 m sprint trail. The OptoJump–Microgate optical measurement system (Optojump, Bolzano, Italy) was used to measure the basic kinematic variables of sprint step: ground contact time, time of step flight phase, step length, step frequency, and step velocity of the nine running steps at maximal velocity including. In a track configuration, the measurement system uses a series of interconnected rods (100 cm x 4 cm x 3 cm) fitted with optical sensors. Each rod (RX bars and TX bars) is fitted with 32 photocells, arranged 4 cm one from another and 0.2 cm above the ground. The rods were distributed along the length and width of the track (20 m x 1.22 m). The device was integrated with a computer for data storage and processing. The fastest time in each distance was selected for statistical analysis.

Means ($\bar{x}$) and standard deviations (*SD*) were calculated for all dependent variables. Student's *t* test was used to examine the differences of somatic variables of between groups. . Fisher's Least Significant Difference (LSD) tests were performed post hoc to determine pairwise differences when significant *F* ratios were obtained. The reliability of the 60 m sprint trail was measured using intraclass correlation coefficient (ICC). This indicated that time for 60 m test (ICC = 0.96) reached high reliability. A statistical power of 0.90 was determined satisfactory and an alpha level of 0.05 was accepted as statistically significant (denoted in bold font).

## Results

Table 1 provides the selected anthropometric and 60 m personal bests of the fast and slow sprinters. Only age and personal bests for 60 m were differ significantly ($p < 0.05$) between groups. The body mass, height, and BMI showed similar level.

Table 1. Descriptive statistics and Student's *t* test results of group age, selected somatic characteristics, and 60 m personal best (PB) times. Values given in bold are significant p ≤ 0.05.

| Variables | Sub-elite | | Elite | | *t* | *p* |
|---|---|---|---|---|---|---|
| | $\bar{x}$ | SD | $\bar{x}$ | SD | | |
| Age (years) | 18.71 | 0.75 | 24.71 | 2.43 | −6.24 | **0.000043** |
| Height (cm) | 182.00 | 5.35 | 179.42 | 3.91 | 0.78 | 0.449165 |
| Body mass (kg) | 73.28 | 4.49 | 74.43 | 8.24 | −0.32 | 0.753007 |
| BMI | 22.17 | 1.10 | 22.79 | 0.74 | −1.22 | 0.244110 |
| 60 m PB | 6.97 | 0.08 | 6.69 | 0.79 | 6.52 | **0.000028** |

No significant changes were observed in CT and FT in either group of sprinters (Figure 1). The difference between CT and FT was ca. 0.04 s and was relatively linear from step two to step eight The linear increases in SL (between steps two and eight in the fast and steps two and six and also step eight in the sub-fast sprinters) were observed in both groups at both time points. The step length SL was maintained at 228 cm and 230 cm (sub-elite and elite, respectively) in the last three steps (Figure 1). The changes in SF were less pronounced and remained relatively similar in the sub-elite group but slightly decreased from 4.38 to 4.33 Hz in the elite group. Considering both SF and SL, the fast sprinters presented greater SF and slightly longer SL than the sub-fast sprinters (Figure 1).

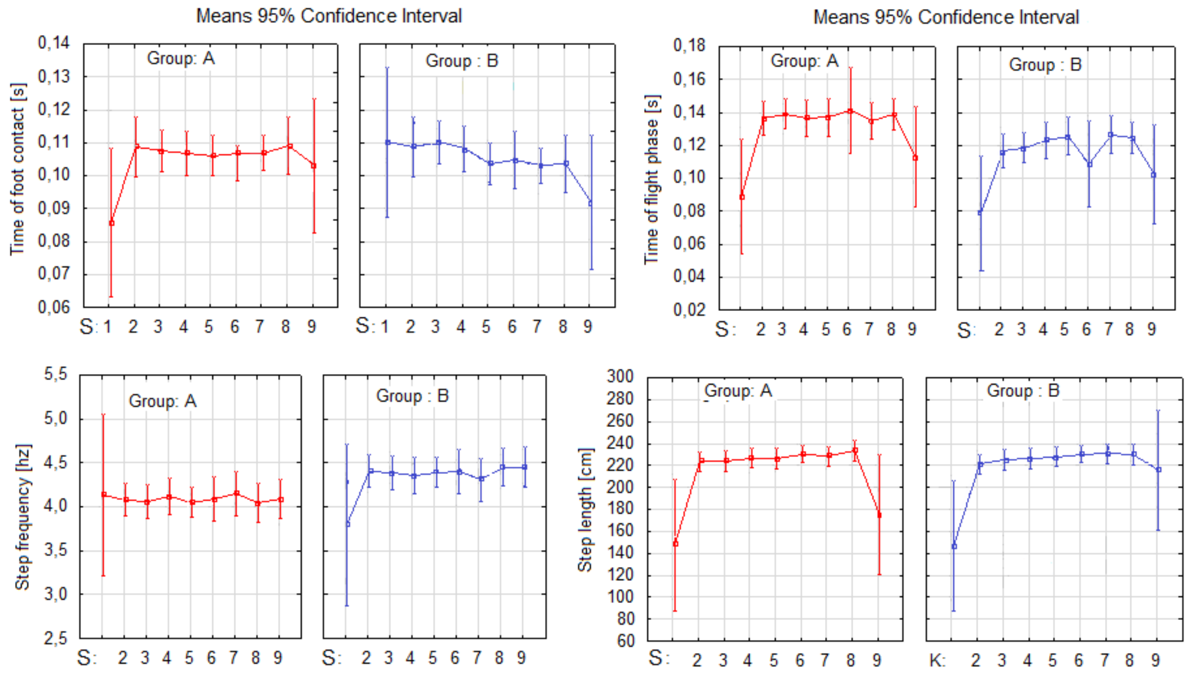


Figure 1. Mean values and confidence interval of selected kinematic parameters of sprinting steps performed during 20-meter faster sprinters (group A) and slower sprinters (group B)

Table 2 presents the analysis of variance for repeated measurements of the basic kinematic parameters of the sprint step measured at a distance of 20 m. It can be clearly seen that the average time of the flight phase showed significant statistical differences both between the groups and the analyzed steps. Similar interaction occurred for the frequency and length of the step. It is clearly visible that these parameters differed statistically significantly.

Table 2. Analysis of variance for repeated measurements of selected kinematic parameters of a running step. Values given in bold are significant $p \leq 0.050$

| Variable | Group | | Steps | | Steps/group | |
|---|---|---|---|---|---|---|
| | F | p | F | p | F | p |
| Time of foot contact [s] | 0,27 | 0,6129 | 2,14 | 0,0388 | 0,74 | 0,6540 |
| Time of flight phase [s] | 9,05 | **0,0109** | 10,58 | **0,0000** | 0,24 | 0,9812 |
| Step frequency [Hz] | 4,91 | **0,0468** | 0,90 | 0,5167 | 1,68 | 0,1121 |
| Step length [cm] | 0,61 | 0,4489 | 18,23 | **0,0000** | 0,25 | 0,9798 |
| Velocity of steps [m/s] | 56,64 | **0,0000** | 8,22 | **0,0000** | 2,06 | **0,0475** |

**Discussion**

The main purpose of the study was to examine the changes of kinematics variables (SL, SF, FT, CT) of sprint step. Our study reported linear increases in SL from steps two to eight, both; in the fast and the sub-fast sprinters). However the step length in the second group was increase only till six step. These results was compared with other research where high performance sprinters were investigated (18, 9, 23, 13, 12,). These studies reported that increase of running speed along with the extension of the running distance, causes changes (lengthening) in the length of steps. This may be explained by the fact that after running 40 m, sprinters from both group was still increasing SL with each step. Therefore the first 40 m can be classified as acceleration phase (build-up phase) where the velocity is still in the process of increasing its value. In turn, the changes in SF were less pronounced and remained relatively similar in the sub-elite group but slightly decreased from 4.38 to 4.33 Hz in the fast group. The sub-fast group showed greater variability similar to SL between the second and sixth step.

The interaction between SL and SF suggests that the improvement in sprint running due to increased velocity does not demonstrate the classic dependency between SL and SF. Hunter et al. (23) found a strong correlation between sprint velocity and SL ($r$ = 0.73) and only a weak correlation between sprint velocity and SF ($r$ = –0.14). However this opinion contradicts the suggestions made by Bezodis et al. (24), who claimed a strong correlation between SF and running velocity ($r$ = 0.886), and a relatively weak correlation ($r$ = –0.192) between SL and running velocity. but a strong correlation between SF and running velocity ($r$ = 0.886) In turn, Mackala (16), who examined whether an increases in SF or SL would increase running velocity, found that SL was more strongly associated with running velocity than SF.

According to Kampmiller et al. (28), Coh et al. (29), and Alcaraz et al. (30) the most important factor in sprint step efficiency is the support phase. The most important seems to be, the ratio between the braking and propulsion phases. In connection with this, it seems important to say that, maximal velocity during sprinting may be achieved only if the force impulse is as small as possible during the braking phase. The foot positioning of the push-off leg as close as possible to the vertical projection of the body's center of gravity on the surface also may be important (28). These two elements are most likely responsible for the times of the support phase and the time of flight phase in each running step. Our experiment did not show significant changes in CT and FT in either group of sprinters (Figure 1) and showed a relatively linear course from step two to step eight. The difference between CT and FT was 0.04 s. CT was more reduced in the elite sprinters. This value was comparable with values reported in other studies during maximal sprinting (90–120 ms) (10, 31, 15). Coh et al.(10) noted a decreasing trend in CT in the first 10 sprint steps after which CT stabilizes.

## Conclusions

It can be clearly seen that the average time of the flight phase, the frequency and length of the step showed significant statistical differences between the groups. Our experiment did not show significant changes in CT and FT in either group of sprinters and showed a relatively linear course from step two to step eight . The velocity of step execution in the fast sprinters showed a linear increase across steps one to nine however no changes in SL between step four and seven was noticed when compared with earlier steps three and six. In turn, the sub-fast sprinters showed more pronounced variation in SV and SL, which may explain the slower running velocity in this group of sprinters. Analysis of the obtained results may be of great importance for coaches. In order to reach a higher value of maximal sprinting speed the optimal interaction between each variables is noteworthy.

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