MIKI 12 (1) (2022): July 13-29
Media Ilmu Keolahragaan Indonesia

p-ISSN 2088-6802 | e-ISSN 2442-6830
https://journal.unnes.ac.id/nju/index.php/miki

Type of Paper: Article

The Analysis of Female 100-Meter Sprinters in Tokyo Olympic Games 2022

Muchamad Arif Al Ardha[*1], Chung Bing Yang[2], Wei Jhe Lin[2], Nurhasan Nurhasan[3], Dwi Cahyo Kartiko[3], Bambang Ferianto Kuntjoro,[3] Nur Shanti Retno Pembayun[3], Kolektus Oki Ristanto[3], Andhega Wijaya[3], Ainun Zulfikar Rizki[3], Catur Supriyanto[3], Sri Sumartiningsih[4]

[1]Physical Education Department, Universitas Negeri Surabaya, Indonesia
[2]Physical Education and Kinesiology Department, National Dong Hwa University, Taiwan
[3]Sport Science Department, Universitas Negeri Surabaya, Indonesia
[4]Sport Science Department, Universitas Negeri Semarang, Indonesia

*Corresponding Author: muchamadalardha@unesa.ac.id

Received: 2022-02-02. Accepted: 2022-04-01. Published: 2022-07-31.

Abstract. This research aimed to identify the performance of the female 100-meter final at the Tokyo Olympic Games 2022. This study was conducted in a quantitative approach and descriptive methods. There were 8 female sprinters aged 28 ± 3.70 years old competing in the 100-meter final at Tokyo Olympic Games 2022. The data were analyzed from a YouTube video on the Olympic channel. The kinematic analysis using Kinovea computer software was conducted to measure the variables in this study. The variables were time per 10 meters (s), velocity per 10-meter (m/s), step per 10-meter (step), and time per step (s). As a result, the champion achieved a stable time in the second to seventh 10-meter (0.77 – 0.84 s) and the fastest average velocity in 100 meters (9.43 m/s). She runs more than 12 m/s in 60 meters distance. It is more consistent than the runner-up (athlete in line 5), who runs more than 12 m/s in 5 10-meter distances. She also achieved 50 steps with an average of 5 steps every 10-meter distance. It is two more than the tallest athlete (173 cm), who achieved 48 steps in 100 meters. The mean time per step of the champion is 0.21 ± 0.03 s/step. In conclusion, step frequency and velocity consistency determined the positive result.

Key words: sprinter; velocity; kinematic; biomechanics

Abstract in Indonesia. Penelitian ini bertujuan untuk mengidentifikasi performa atlet sprinter 100 meter putri di Olimpiade Tokyo 2022. Penelitian ini dilakukan secara kuantitatif dan metode deskriptif. Ada 8 sprinter putri berusia 28 ± 3,70 tahun yang bertanding di final 100 meter pada Olimpiade Tokyo 2022. Data dianalisis dari video YouTube Chanel resmi Olimpiade dengan metode kinematika pada software komputer Kinovea. Variabel dalam penelitian ini adalah waktu per 10 meter (s), kecepatan per 10 meter (m/s), langkah per 10 meter (langkah), dan waktu per langkah.. Hasilnya, pemenang lomba mencapai waktu yang stabil di 10 meter kedua hingga ketujuh (0,77 – 0,84 detik) serta kecepatan rata-rata tercepat dalam 100 meter (9,43 m/s). Dia berlari lebih dari 12 m/s dalam jarak 60 meter. Ini lebih konsisten daripada runner-up yang berlari lebih dari 12 m/s dalam jarak 50 meter. Dia juga mencapai total 50 langkah dengan rata-rata 5 langkah di setiap jarak 10 meter. Ini adalah dua langkah lebih banyak dari atlet tertinggi (173 cm) yang mencapai 48 langkah dalam 100 meter. Waktu rata-rata per langkah adalah 0,21 ± 0,03 detik/langkah. Kesimpulannya, konsistensi frekuensi dan kecepatan langkah menentukan hasil positif.

Kata Kunci: sprint; kecepatan; kinematik; biomekanik

How to Cite: Ardha, M. A. A., Yang, C. B., Lin, W. J., Nurhasan, N., Kartiko, D., Kuntjoro, B. F., Pembayun, N. S. R., Ristanto, K. O., Wijaya, A., Rizki, A. Z., Supriyanto, C., Sumartiningsih, S. (2022). The Analysis of Female 100-Meter Sprinters in Tokyo Olympic Games 2022. *MIKI: Media Ilmu Keolahragaan Indonesia 12 (1): July,* 13-29.

DOI: http://dx.doi.org/10.15294/miki.v12i1.37858

INTRODUCTION

The 100 meters sprint in track and field requires an athlete to react quickly to the starting gun, leave the starting beams explosively, accelerate to the maximum, and maintain speed as long as possible until the end of the race field (Cissik, 2010). Reaction time refers to the time from the moment the gun is fired until the athletes make a response leaving the start block (Cissik, 2010). The reaction time is mainly in the range of 0.12 to 0.18 seconds(Korhonen et al., 2009). The running velocity is the optimal relationship between stride length, step speed, and proper sprint techniques(Mattes et al., 2021). The kinematics of touchdown and take-off is essential for high stroke frequencies in the same stride length, and the kinematics of the forward swing foot is essential for long stride lengths in the same stride frequency field(Toyoshima & Sakurai, 2016).

The running speed is the multiplication result of stroke frequency and length, where one step consists of the contact with the ground and the subsequent airtime (Rabita et al., 2015). To achieve faster speeds, sprinters usually increase the frequency of steps and stride length (Soemaredjo, 2021; Weyand et al., 2000). The stride length can be calculated as a product of the contact length or distance travelled by the centre of mass during soil contact, and the vertical soil reaction force averages the relative attitude to body weight (Taboga et al., 2020). The sprinters coordinate the movement of their lower extremities and torso in the same way during the initial phase and the initial acceleration, which contributes to a new conceptual understanding of the mechanism that sustains performance and the early acceleration field (I. N. Bezodis et al., 2019).

Elite female athletes have specific characteristics (Mohapatra, 2021). Furthermore, female sprinters may have different characteristics than males (Krech, 2017). In the physiological aspect, female sprinters could reduce the fat percentage to increase performance rather than increase their muscle mass (Abe et al., 2019). The hormonal differences could also potentially lead female athletes to experience more injuries (McGroarty et al., 2020). However, there is still limited study about female athletes than male. This study aims to analyze the female sprinters' performance in the final 100 meters of the Tokyo 2020 Olympics. The female sprinters' performance includes the time per 10 meters, velocity per 10-meter, step per 10-meter, incremental steps, and time per step. This data will enrich the information and knowledge of female sprinters' performance.

METHODS

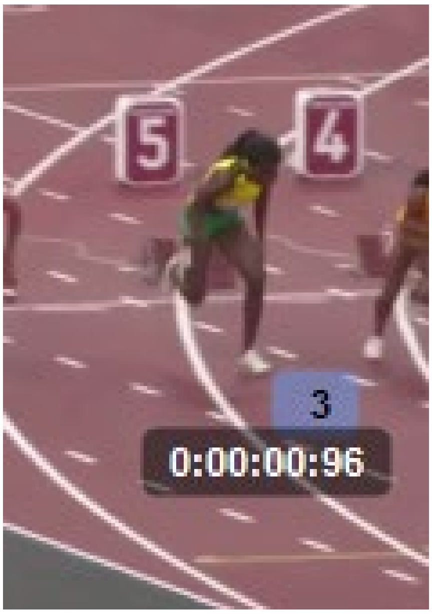
A quantitative study was conducted by descriptive analysis. 8 female sprinters (28 ± 3.70 years old) were observed in this study (Table 1). The data were analyzed from a YouTube video of the Olympic channel (https://www.youtube.com/watch?v=7pgoMCc08yA). The kinematic analysis using Kinovea computer software was conducted to measure the variables in this study (Figure 1). The variables observed in this study were time per 10 meters, velocity per 10-meter, step per 10-meter, incremental steps, and time per step. Furthermore, descriptive analysis by SPSS computer software was performed to analyze each athlete's performance.

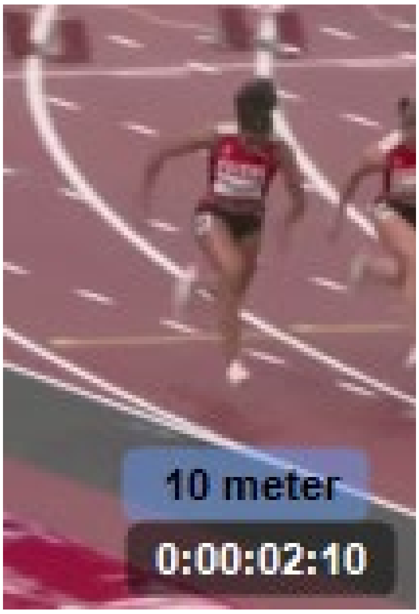
RESULTS AND DISCUSSION

Based on the result in **Table 2.** time per 10-meter, each athlete took more than 2 seconds in the first 10 meters. Most of them shorten the time to less than 1 second in the second 10-meter (20 meters) to the eighth 10-meter (80 meters). Most of them took more than 1 second in the two last 10-meter. However, the champion (athlete in line 4) showed a stable time in the second to seventh 10-meter (0.77 – 0.84 s). She also achieved the fastest time in the two last 10-meter compared with most of the athletes except the athlete in line 3. Then she tried to decrease the time in the last 40 meters. The athlete in line 3 is the only athlete who increases the time in the 50 and 60-meter up to

Table 1. Research Sample

Line	Name	Nat.	Age	Height (cm)	Weight (kg)	Time	Rank
2	Daryll Neita	GBR	24	172	61	11.02	7
3	Teahna Daniels	USA	24	170	70	11.12	8
4	Eleina Thompson-Herah	JAM	29	168	52	10.61	1
5	Shelly-ann Fraser Pryce	JAM	34	152	52	10.74	2
6	Marie-Josee Ta Loiu	CIV	32	158	50	10.91	4
7	Shericka Jackson	JAM	27	173	61	10.76	3
8	Ajla Del Ponte	SUI	25	168	56	10.97	5
9	Mujinga Kambundji	SUI	29	168	65	10.99	6
Mean			28.00	16.12	58.37	10.89	
SD			3.70	7.29	7.06	0.17	





(a) (b)

Figure 1. (a) Time per distance; (b) Time per step;

1.44 seconds.

In **Table 3.** the champion (athlete in line 4) performed the fastest average velocity (9.43 m/s), with the average velocity in every 10 meters distance being 10.59 m/s. She runs more than 12 m/s in 6 10-meters distance. It is more consistent than the runner-up (athlete in line 5), who runs more than 12 m/s in a 5 10-meter distance. The fastest velocity in a 10-meter distance is 16.67 m/s, achieved by the athlete in line 9 in the seventh 10-meter distance. On the other hand, her velocity is the slowest among other athletes in the fourth 10-meter distance (10.75 m/s) and the tenth/last 10-meter distance (6.13 m/s).

In **Table 4.** athletes in lines 8 and 9 performed the most step (52 steps), with the intermediate step in every 10 meters distance being 5.30 steps. The champion (athlete in line 4) and runner-up (athlete in line 5) achieved a total of 50 steps with an average of 5 steps every 10-meter distance. Furthermore, the tallest athlete (173 cm) also the third champion (athlete in line 7) took 48 steps in 100 meters, with the intermediate step in every 10-meter distance being 4.8 steps. It is similar to the athlete in line 3, 172 cm in height (48 steps), and the athlete in line 2, 173 cm in height (49 steps).

Table 2. Time per 10 meter (s)

Distance	Line							
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**
10	2.23	2.33	2.33	2.33	2.40	2.33	2.40	2.10
20	1.00	0.90	0.83	0.87	0.73	0.90	0.90	0.93
30	0.83	0.83	0.84	0.86	0.90	0.83	0.83	0.87
40	0.70	0.84	0.83	0.77	0.90	0.80	0.73	0.93
50	0.97	1.16	0.80	0.80	0.87	0.84	0.97	0.83
60	0.97	1.44	0.83	0.83	0.83	0.93	0.80	0.97
70	0.66	0.83	0.80	0.77	0.80	0.70	0.83	0.60
80	0.94	0.73	0.77	0.83	0.77	0.77	0.84	0.87
90	1.23	0.99	1.23	1.30	1.33	1.30	1.30	1.26
100	1.49	1.07	1.35	1.38	1.38	1.36	1.37	1.63
Total	11.02	11.12	10.61	10.74	10.91	10.76	10.97	10.99
Mean	1.10	1.11	1.06	1.07	1.09	1.08	1.10	1.10
SD	0.46	0.48	0.49	0.49	0.51	0.49	0.51	0.45

Table 3. Velocity per 10 meters (m/s)

Distance	Line							
	2	3	4	5	6	7	8	9
10	4.48	4.29	4.29	4.29	4.17	4.29	4.17	4.76
20	10.00	11.11	12.05	11.49	13.70	11.11	11.11	10.75
30	12.05	12.05	11.90	11.63	11.11	12.05	12.05	11.49
40	14.29	11.90	12.05	12.99	11.11	12.50	13.70	10.75
50	10.31	8.62	12.50	12.50	11.49	11.90	10.31	12.05
60	10.31	6.94	12.05	12.05	12.05	10.75	12.50	10.31
70	15.15	12.05	12.50	12.99	12.50	14.29	12.05	16.67
80	10.64	13.70	12.99	12.05	12.99	12.99	11.90	11.49
90	8.13	10.10	8.13	7.69	7.52	7.69	7.69	7.94
100	6.71	9.35	7.41	7.25	7.25	7.35	7.30	6.13
Average Velocity	9.07	8.99	9.43	9.31	9.17	9.29	9.12	9.10
Mean	10.21	10.01	10.59	10.49	10.39	10.49	10.28	10.23
SD	3.23	2.81	2.93	2.99	3.05	3.09	2.97	3.34

Furthermore, athletes who are less than 170 cm needs 50 or more steps.

The mean of time per step is about 0.21 – 0.23 s. However, every athlete takes more than 0.35 s in the first step and constantly decreases until the finish line. The champion (athlete in line 4) and runner-up (athlete in line 5) showed the same mean (0.21 s) and SD (0.03 s) with a total of 50 steps for a 100-meter distance.

Sprinter athletes must run at the curtain distance at the maximum possible speed (Subhan Zuhdi, 2013). The maximum velocity during 100-meter running is strongly related to the physical components (Slawinski et al., 2017). Furthermore, physical components are essential for sprinters (Purnomo et al., 2020). The physical component of each athlete is also determined by the interaction of physiological and biomechanical factors (Beattie et al., 2020). The physical components are strength, speed, the explosive power of the limb muscles, reaction speed, and agility (Yuwono & Pramono, 2019). In addition, balance and coordination are also necessary to support the runner's speed (Prasetyo & Djawa, 2021). The power of the limb muscles is dominated from the starting position until the athlete touches the finish line. Lower body isometric forces on the sprinter contributed positively to the starting position (Suprapto et al., 2019; Brady et al., 2020).

The sprinter's success is also supported by a genetically determined physiological character

Table 4. Steps per 10 meter (step)

Distance	Line							
	2	3	4	5	6	7	8	9
10	10	10	10	10	10	10	10	10
20	5	4	4	4	4	4	5	5
30	4	5	5	5	5	5	5	5
40	4	4	4	4	4	4	5	5
50	4	4	5	4	4	4	4	5
60	5	4	4	4	5	4	4	4
70	4	4	4	4	4	4	4	5
80	4	4	4	4	4	5	5	4
90	6	6	6	7	6	6	7	6
100	3	3	4	4	5	2	4	4
Total	49	48	50	50	51	48	53	53
Mean	4.90	4.80	5.00	5.00	5.10	4.80	5.30	5.30
SD	1.97	1.99	1.89	2.00	1.85	2.10	1.89	1.77

Table 5. Time per step (s)

No	Line							
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	0.4	0.36	0.36	0.36	0.4	0.43	0.36	0.36
2	0.26	0.3	0.27	0.3	0.23	0.3	0.27	0.17
3	0.2	0.24	0.2	0.2	0.23	0.23	0.23	0.2
4	0.3	0.23	0.23	0.24	0.24	0.24	0.2	0.23
5	0.17	0.23	0.2	0.2	0.2	0.23	0.24	0.2
6	0.27	0.24	0.2	0.26	0.2	0.27	0.23	0.2
7	0.16	0.2	0.2	0.17	0.2	0.23	0.23	0.2
8	0.24	0.2	0.2	0.23	0.23	0.2	0.2	0.17
9	0.26	0.26	0.2	0.2	0.2	0.2	0.2	0.23
10	0.2	0.2	0.2	0.24	0.2	0.23	0.24	0.2
11	0.2	0.24	0.2	0.16	0.2	0.2	0.23	0.2
12	0.24	0.2	0.2	0.2	0.17	0.2	0.17	0.17
13	0.2	0.2	0.2	0.2	0.23	0.2	0.23	0.23
14	0.23	0.26	0.2	0.2	0.2	0.24	0.2	0.17
15	0.2	0.2	0.2	0.17	0.2	0.2	0.23	0.2
16	0.23	0.2	0.2	0.23	0.2	0.2	0.2	0.2
17	0.2	0.24	0.2	0.17	0.2	0.23	0.2	0.2
18	0.2	0.23	0.24	0.2	0.2	0.23	0.2	0.2
19	0.24	0.2	0.2	0.2	0.2	0.2	0.2	0.2
20	0.23	0.23	0.2	0.2	0.2	0.24	0.2	0.2
21	0.23	0.2	0.2	0.2	0.2	0.2	0.2	0.2
22	0.17	0.15	0.16	0.2	0.2	0.2	0.24	0.2
23	0.23	0.29	0.2	0.2	0.2	0.2	0.2	0.2
24	0.24	0.2	0.2	0.2	0.2	0.23	0.2	0.17
25	0.23	0.23	0.2	0.2	0.2	0.2	0.23	0.23
26	0.2	0.23	0.2	0.2	0.2	0.2	0.2	0.17
27	0.2	0.2	0.24	0.17	0.23	0.2	0.2	0.2
28	0.2	0.2	0.16	0.23	0.2	0.2	0.2	0.2
29	0.23	0.24	0.24	0.17	0.2	0.23	0.2	0.2
30	0.2	0.23	0.2	0.2	0.2	0.2	0.2	0.2
31	0.3	0.23	0.2	0.2	0.2	0.2	0.2	0.2
32	0.2	0.2	0.2	0.2	0.24	0.2	0.23	0.2
33	0.24	0.24	0.16	0.2	0.2	0.24	0.24	0.2
34	0.23	0.23	0.24	0.2	0.2	0.2	0.16	0.2
35	0.2	0.2	0.2	0.2	0.2	0.2	0.24	0.2
36	0.23	0.2	0.2	0.23	0.2	0.23	0.23	0.2
37	0.24	0.23	0.2	0.2	0.2	0.23	0.2	0.23
38	0.2	0.24	0.23	0.2	0.26	0.24	0.2	0.17
39	0.26	0.2	0.2	0.2	0.2	0.2	0.23	0.23
40	0.24	0.26	0.2	0.2	0.2	0.2	0.17	0.2
41	0.23	0.2	0.2	0.2	0.24	0.23	0.23	0.2
42	0.23	0.24	0.2	0.2	0.2	0.2	0.24	0.2
43	0.24	0.26	0.23	0.2	0.23	0.2	0.2	0.2
44	0.21	0.2	0.2	0.23	0.2	0.23	0.23	0.2
45	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.23
46	0.17	0.27	0.2	0.2	0.23	0.24	0.23	0.2
47	0.15	0.23	0.27	0.24	0.24	0.2	0.24	0.24
48	0.23	0.27	0.2	0.2	0.2	0.23	0.23	0.16
49	0.24		0.2	0.2	0.2		0.23	0.27
50			0.23	0.26	0.26		0.2	0.2
51					0.24			0.23
52								0.2
53								0.24
Total Step	49	48	50	50	51	48	49	53
Mean	0.22	0.23	0.21	0.21	0.21	0.22	0.22	0.21
SD	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.03

(Morrison & Cooper, 2006). The sprinter needs specific musculoskeletal characteristics of the legs to support their performance (Bex et al., 2017). In addition, body size and composition also significantly impact athletes' level of performance (Barbieri et al., 2017). Top runners have a large circumference of calves, thighs, and upper arms and a fat-free body mass index (Barbieri et al., 2017). The musculoskeletal structure of the foot and ankle can potentially influence the performance of the human sprint in a complex way (Lee & Piazza, 2009). The strength of the upper limbs and lower limb muscles become the determinants of the sprinter athletes' achievement (Aikawa et al., 2020). The kinematic analysis of movement also explains that the length and frequency of steps are influenced by the length of the foot (Toyoshima & Sakurai, 2016). The anthropometric characteristic and running movement technique analysis can provide a complete evaluation of the runner's performance (Zaccagni et al., 2019).

Coaches and sports scientists are trying to improve athletes' sprint performance (Simitzi et al., 2021). As a result, modern sprinter training systems emphasize the components of muscle strength and explosive power (Vrublevskiy et al., 2019). Muscle strength is essential to determining speed (Sandstedt et al., 2013). The maximum speed is also associated with the ground reaction force (GRF) on the vertical jump performance (Taboga et al., 2020). The ground reaction force is associated with every step of a sprinter (Colyer et al., 2018). Furthermore, ground reaction force can also be maximized by the hips' extensive angle during the detachment phase in the start block (N. E. Bezodis et al., 2015). In addition, muscle strength not only supports performance but also avoids the injuries that potentially occur (Sugiura et al., 2021).

Sprinters' frequent injuries include hamstring and achilles tendons (Loturco et al., 2021). The potential for hamstring injuries in sprinter runners can be lowered by increasing the training portion of agility and flexibility (Sugiura et al., 2017). Flexibility, in this case, is interpreted as the joint motion used when running (Suharti et al., 2019). So, flexibility is necessary to compensate for the stress in every joint in carrying out running movements (De Lima et al., 2019). The level of flexibility is also influenced by several factors, including age, gender, and body composition (Minatto et al., 2010; Vanhelst et al., 2016). Agility is also the main physical component of sprinter runners (Ortega et al., 2008; Sheppard & Young, 2006). Agility training directly affects the athlete's physical condition (Li et al., 2020). In addition, the athlete's ability to take maximum oxygen (VO2 max) must be considered in athlete training (Irving et al., 2013).

CONCLUSION

Elite female sprinters performed very well in the 100-Meter final in Tokyo Olympic Games 2022. They achieved, on average, 10.89 ± 0.17 seconds in 100 meters, with the fastest time at 10.61 and the slowest at 11.12. There is only a 0.51-second time difference between the champion and the last. They analyze several other differences in their performance among the sprinters. An example is the champion performance analysis. She achieved a stable time in the second to seventh 10-meter (0.77 – 0.84 s) and the fastest average velocity in 100 meters (9.43 m/s). She runs more than 12 m/s in 60 meters distance. It is more consistent than the runner-up (athlete in line 5), who runs more than 12 m/s in 5 10-meter distances. She also achieved 50 steps with an average of 5 steps every 10-meter distance. It is two more than the tallest athlete (173 cm), who achieved 48 steps in 100 meters. The mean time per step of the champion is 0.21 ± 0.03 s/step. On the other hand, the female sprinter who achieved the slowest time (11.12 seconds) achieved the fastest in the 70-80 meters (13.70 m/s). However, she could not manage the consistency of her velocity and dropped the velocity to 6.94 m/s in the 50-60 meters. In conclusion, step frequency and velocity consistency determined the positive result.

AUTHOR CONTRIBUTIONS

The conceptualization, M.A.A. and C.S..; methodology, C.B.Y.; software, A.R..; validation, N.N., D.C.K., B.F.Y. and N.S.P.; formal analysis, K.O.R..; investigation, S.S.; resources, A.W. and W.J.L.

ACKNOWLEDGMENTS

This article was developed by collaboration study among Universitas Negeri Surabaya (Indonesia), National Dong Hwa University (Taiwan), and Universitas Negeri Semarang (Indonesia).

CONFLICTS OF INTEREST

We confirmed that there is no conflict of interest regarding the publication of this paper. Furthermore, this study was developed to provide knowledge of science regarding the elite female sprinters' performance.

REFERENCES

Abe, T., Kawamoto, K., Dankel, S. J., Bell, Z. W., Spitz, R. W., Wong, V., & Loenneke, J. P. (2019). Longitudinal associations between body composition changes and performance changes in elite female sprinters. *20*(1), 100–105.https://doi.org/10.1080/17461391.2019.16 12950

Aikawa, Y., Murata, M., & Omi, N. (2020). Relationship of height, body mass, muscle mass, fat mass, and fat percentage with athletic performance in male Japanese college sprinters, distance athletes, jumpers, throwers, and decathletes. *The Journal of Physical Fitness and Sports Medicine*, *9*(1). https://doi.org/10. 7600/jpfsm.9.7

Barbieri, D., Zaccagni, L., Babić, V., Rakovac, M., Mišigoj-Duraković, M., & Gualdi-Russo, E. (2017). Body composition and size in sprint athletes. *Journal of Sports Medicine and Physical Fitness*, *57*(9). https://doi.org/10.2373 6/S0022-4707.17.06925-0

Beattie, K., Tawiah-Dodoo, J., & Graham-Smith, P. (2020). Countermovement Jump Characteri stics of World-Class Elite and Sub-Elite Male Sprinters. *Sports Performance and Science Reports*, *7*(1).

Bex, T., Iannaccone, F., Stautemas, J., Baguet, A., De Beule, M., Verhegghe, B., Aerts, P., De Clercq, D., & Derave, W. (2017). Discriminant musculoskeletal leg characteristics between sprint and endurance elite Caucasian runners. *Scandinavian Journal of Medicine and Science in Sports*, *27*(3). https://doi.org/10.1111/sms. 12649

Bezodis, I. N., Brazil, A., von Lieres und Wilkau, H. C., Wood, M. A., Paradisis, G. P., Hanley, B., Tucker, C. B., Pollitt, L., Merlino, S., Vazel, P.-J., Walker, J., & Bissas, A. (2019). World-Class Male Sprinters and High Hurdlers Have Similar Start and Initial Acceleration Techniques. *Frontiers in Sports and Active Living*, *1*. https://doi.org/10.3389/fspor.2019.00023

Bezodis, N. E., Salo, A. I. T., & Trewartha, G. (2015). Relationships between lower-limb kinematics and block phase performance in a cross-section of sprinters. *European Journal of Sport Science*, *15*(2), 118–124. https://doi.org /10.1080/17461391.2014.928915

Brady, C. J., Harrison, A. J., Flanagan, E. P., Gregory Haff, G., & Comyns, T. M. (2020). The relationship between isometric strength and sprint acceleration in sprinters. *International Journal of Sports Physiology and Performance*, *15*(1). https://doi.org/10.1123/ijspp.2019-0151

Cissik, J. M. (2010). Strength and conditioning considerations for the 100-m sprinter. *Strength and Conditioning Journal*, *32*(6). https:// doi.org/10.1519/SSC.0b013e3181fd9e34

Colyer, S. L., Nagahara, R., Takai, Y., & Salo, A. I. T. (2018). How sprinters accelerate beyond the velocity plateau of soccer players: Waveform analysis of ground reaction forces. *Scandinavian Journal of Medicine and Science in Sports*, *28*(12). https://doi.org/10.1111/sms. 13302

De Lima, T. R., Martins, P. C., Moraes, M. S., & Santos Silva, D. A. (2019). Association of flexibility with sociodemographic factors, physical activity, muscle strength, and aerobic fitness in adolescents from southern Brazil. *Revista Paulista de Pediatria*, *37*(2). https://doi.org/10.1590/1984-0462/;2019;37;2; 00005

Irving, R., Charlton, V., Morrison, E., Facey, A., & Buchanan, O. (2013). Demographic characteristics of world-class Jamaican sprinters. *The Scientific World Journal*, *2013*. https://doi.org/10.1155/2013/670217

Korhonen, M. T., Mero, A. A., AlIn, M., Sipila, S., Hakkinen, K., Liikavainio, T., Viitasalo, J. T., Haverinen, M. T., & Suominen, H. (2009). Biomechanical and skeletal muscle determinants of maximum running speed with aging. *Medicine and Science in Sports and Exercise*, *41*(4). https://doi.org/10.1249/MS S.0b013e3181998366

Krech, M. (2017). To Be a Woman in the World of Sport: Global Regulation of the Gender Binary in Elite Athletics. *Berkeley Journal of International Law*, *35*. https://heinonline.org /HOL/Page?handle=hein.journals/berkjintlw35 &id=273&div=&collection=

Lee, S. S. M., & Piazza, S. J. (2009). Built for speed: Musculoskeletal structure and sprinting ability. *Journal of Experimental Biology*, *212*(22). https://doi.org/10.1242/jeb.031096

Li, Y., Xia, X., Meng, F., & Zhang, C. (2020). Association Between Physical Fitness and Anxiety in Children: A Moderated Mediation Model of Agility and Resilience. *Frontiers in*

Public Health, *8*. https://doi.org/10.3389/fpubh.2020.00468

Loturco, I., de la Fuente, C., Bishop, C., Nichioka, H., Lessio, D., Moreno, C. T., Pereira, L. A., & Carpes, F. P. (2021). Video-based biomechanical analysis of an unexpected Achilles tendon rupture in an Olympic sprinter. *Journal of Biomechanics*, *117*, 110246. https://doi.org/10.1016/J.JBIOMECH.2021.110246

Mattes, K., Wolff, S., & Alizadeh, S. (2021). Kinematic Stride Characteristics of Maximal Sprint Running of Elite Sprinters-Verification of the "swing-Pull Technique." *Journal of Human Kinetics*, *77*(1). https://doi.org/10.2478/hukin-2021-0008

McGroarty, N. K., Brown, S. M., & Mulcahey, M. K. (2020). Sport-Related Concussion in Female Athletes: A Systematic Review. *Orthopaedic Journal of Sports Medicine*, *8*(7), 2325967120932306. https://doi.org/10.1177/2325967120932306

Minatto, G., Ribeiro, R. R., Junior, A. A., & Santos, K. D. (2010). Influence of age, sexual maturation, anthropometric variables and body composition on flexibility. *Revista Brasileira de Cineantropometria e Desempenho Humano*. https://doi.org/10.5007/1980-0037.2010v12n3p151

Mohapatra, S. (2021). 'We Are Equal but Different': Challenging Compulsory Heterosexuality by Intersexual Female Athletes in the World of Sport: *70* (3), 291–313. https://doi.org/10.1177/00380229211011855

Morrison, E. Y. S. A., & Cooper, P. D. (2006). Some bio-medical mechanisms in athletic prowess. In *West Indian Medical Journal* (Vol. 55, Issue 3). https://doi.org/10.1590/S0043-31442006000300015

Ortega, F. B., Ruiz, J. R., Castillo, M. J., & Sjöström, M. (2008). Physical fitness in childhood and adolescence: A powerful marker of health. In *International Journal of Obesity* (Vol. 32, Issue 1). https://doi.org/10.1038/sj.ijo.0803774

Prasetyo, yogi mahendra, & Djawa, B. (2021). Tingkat Kebugaran Jasmani Ekstrakurikuler Karate Di SMA Negeri 2 Surabaya Yogi Mahendra Prasetyo *, Bernard Djawa. *Jurnal Pendidikan Olahraga Dan Kesehatan*, *9*(1).

Purnomo, E., Irianto, J. P., & Mansur, M. (2020). Respons molekuler beta endorphin terhadap variasi intensitas latihan pada atlet sprint. *Jurnal Keolahragaan*, *8*(2). https://doi.org/10.21831/jk.v8i2.33833

Rabita, G., Dorel, S., Slawinski, J., Sàez-de-Villarreal, E., Couturier, A., Samozino, P., & Morin, J. B. (2015). Sprint mechanics in world-class athletes: A new insight into the limits of human locomotion. *Scandinavian Journal of Medicine and Science in Sports*, *25*(5), 583–594. https://doi.org/10.1111/sms.12389

Sandstedt, E., Fasth, A., Eek, M. N., & Beckung, E. (2013). Muscle strength, physical fitness and well-being in children and adolescents with juvenile idiopathic arthritis and the effect of an exercise programme: A randomized controlled trial. *Pediatric Rheumatology*, *11*(1). https://doi.org/10.1186/1546-0096-11-7

Sheppard, J., & Young, W. (2006). Agility literature review: Classifications, training and testing. In *Journal of Sports Sciences* (Vol. 24, Issue 9). https://doi.org/10.1080/02640410500457109

Simitzi, V., Tsoukos, A., Kostikiadis, I. N., Parotsidis, C. A., Paizis, C., Nassis, G. P., & Methenitis, S. K. (2021). The Acute Effects Of Different High-Intensity Conditioning Activities On Sprint Performance Differ Between Sprinters Of Different Strength And Power Characteristics. *Kinesiology*, *53*(2). https://doi.org/10.26582/K.53.2.2

Slawinski, J., Termoz, N., Rabita, G., Guilhem, G., Dorel, S., Morin, J. B., & Samozino, P. (2017). How 100-m event analyses improve our understanding of world-class men's and women's sprint performance. *Scandinavian Journal of Medicine and Science in Sports*, *27*(1), 45–54. https://doi.org/10.1111/sms.12627

Soemaredjo, B. sujiono. (2021). Studi Literasi Tentang Frekuensi Langkah Dan Panjang Langkah Pada Kecepatan Lari Sprint 100 Meter. *Jurnal Ilmiah Sport Coaching and Education*, *5*(1).

Subhan Zuhdi, M. (2013). Analisis Gerak Lari Sprint 60 Meter Secara Biomekanika. *Jurnal Kesehatan Olahraga*, *1*(2).

Sugiura, Y., Sakuma, K., Fujita, S., & Sakuraba, K. (2021). Hamstring Injury Prevention Program and Recommendation for Stride Frequency during Tow-Training Optimization. *Applied Sciences 2021, Vol. 11, Page 6500*, *11*(14), 6500. https://doi.org/10.3390/APP11146500

Sugiura, Y., Sakuma, K., Sakuraba, K., & Sato, Y. (2017). Prevention of Hamstring Injuries in Collegiate Sprinters. *Orthopaedic Journal of Sports Medicine*, *5*(1). https://doi.org/10.1177/2325967116681524

Suharti, Nurhasan, & Wiriawan, O. (2019). The influence of physical fitness gymnastics 2017 and Indonesian Jaya gymnastics toward flexibility and endurance. *Annals of Tropical Medicine and Public Health*, *22*(11). https://doi.org/10.36295/ASRO.2019.221119

Suprapto, J., Supriyadi, S., & Merawati, D. (2019). Pengaruh Latihan Beban Leg Press Dan Squat Terhadap Power Otot Tungkai Pelari Di Pasi Kota Malang. *Jurnal Sport Science*, *9*(2). https://doi.org/10.17977/um057v9i2p163-170

Taboga, P., Beck, O. N., & Grabowski, A. M. (2020). Prosthetic shape, but not stiffness or height, affects the maximum speed of sprinters with bilateral transtibial amputations. *PLoS ONE*, *15*(2). https://doi.org/10.1371/journal.pone.0229035

Toyoshima, R., & Sakurai, S. (2016). Kinematic Characteristics of High Step Frequency Sprinters and Long Step Length Sprinters at Top Speed Phase. *International Journal of Sport and Health Science*, *14*(0). https://doi.org/10.5432/ijshs.201515

Vanhelst, J., Fardy, P. S., Chapelot, D., Czaplicki, G., & Ulmer, Z. (2016). Physical fitness levels of adolescents in the Ile de France region: comparisons with European standards and relevance for future cardiovascular risk. *Clinical Physiology and Functional Imaging*, *36*(6). https://doi.org/10.1111/cpf.12253

Vrublevskiy, E. P., Khorshidakhmed, K. S., & Albarkaii, D. A. (2019). Focused strength and speed-strength training of sprinters. *Teoriya i Praktika Fizicheskoy Kultury*, *2019*(4).

Weyand, P. G., Sternlight, D. B., Bellizzi, M. J., & Wright, S. (2000). Faster top running speeds are achieved with greater ground forces, not more rapid leg movements. *Journal of Applied Physiology*, *89*(5). https://doi.org/10.1152/jappl.2000.89.5.1991

Yuwono, T., & Pramono, M. (2019). Analisis Faktor Kondisi Fisik yang Paling Mempengaruhi Sprint 100 Meter Pada Sprinter PASI Sidoarjo. *Jurnal Kesehatan Olahraga*, *7*(2).

Zaccagni, L., Lunghi, B., Barbieri, D., Rinaldo, N., Missoni, S., Šaric, T., Šarac, J., Babic, V., Rakovac, M., Bernardi, F., & Gualdi-Russo, E. (2019). Performance prediction models based on Croatian sprinters' anthropometric, genetic and psychological traits. *Biology of Sport*, *36*(1). https://doi.org/10.5114/biolsport.2018.78901