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The impact of rule updates on the performance of racewalkers and the classification of countries: An analysis at the Olympic Games

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ABSTRACT

Numerous controversies arose over the judgment of the racewalking events, and the rules were amended more than once. Before 1995, the rule required constant touch with the ground, and the need for a straight knee was only applied in the upright vertical posture. While, after 1995, the rule that applies today was published, which included two obvious changes. One related to maintaining a constantly straight knee through the first half of the stride, and the other to maintaining contact as seen by the human eye. This study aimed to investigate the impact of the last three modifications in racewalking rules on elite athletes' performance, athletes' eligibility, and nations' classification. Also, we investigated the regression between performance times of 20, and 50 km events and explanatory variables (BMI, and age). We collected data of 310 racewalkers from Olympic Games records (men) in 20km and 50km between 1956 and 2016. This period was divided into three stages according to the racewalking rules updates: Stage A (from 1996 to 2016), Stage B (from 1976 to 1992), and Stage C (from 1956 to 1972). There was a significant difference between all stages favoring stage A for Athlete’s Performance. Stage A has the highest speeds (4.06±.23m/sec) for 20km with large ES ($\eta 2$=.54, p=.000), and (3.71±.06m/sec) for 50km with large ES ($\eta 2$=.769, p=.000) compared to others. The participants had the efficiency and the ability to finish the race with the least percentage of withdrawals under the current rule compared to other rules. Some countries emerged on the scene, i.e. China, Poland and Ecuador, and others disappeared under the current rule; while the regression model's results revealed a substantial link between time and explanatory parameters where (BConstant=58.219, P.000) for 20km and (BConstant=164.744, P.000) for 50km. Results proved that the elite walkers, the youngest and lowest in BMI, are the fastest and most efficient walkers under the current rule.

KEYWORDS

Race Walking; Loss of Contact; Bent Knee; Disqualified; Explanatory Parameters; Prediction

1. INTRODUCTION

Racewalking is the competitive form of athletic walking within athletics and it's a long-distance footrace in which the athletes must walk and not run. Although it may look easy, racewalking is in reality very difficult (Megahed & Tarek, 2023). In current rules, it differs from running in that the forward leg must be straightened from the time it first touches the ground until it reaches a straight vertical position with no visible loss (to the human eye) loss of contact feet. As a result, race walking is subject to stringent regulations governing its technique that follows International Association of Athletics Federations (IAAF) rules 230,2 (IAAF Rules, 2020). Racewalking originally appeared as a solo sport as a men's event at the 1908 Games in London, with a 3500 m and a 10-mile racewalk. Many disputes had developed over the judging of racewalking events and have been replaced more than once until it has settled into just two races (50 km and 20 km). Both are held road events with the less controversial (Jürgen, 2008; Marlow, 1990). The 50 km (men) racewalk became part of the Olympics schedule in 1932 (IAAF, 2022b) (Megahed et al., 2021) and the 20 km in the 1956 Olympics for men (IAAF, 2022a).

The IAAF published the first rule of race walking in 1927 that was used for judging in all universal competitions: “Walking is progression by steps so taken that unbroken contact with the ground is maintained“ (IAAF rule 51 in 1927) (IAAF, 1928). In 1949, the previous rule was developed to be: “Walking is progression by steps so taken that unbroken contact with the ground is maintained. At each step, the advancing foot of the walker must make contact with the ground before the rear foot leaves the ground” (IAAF rule 45,1 in 1949) (IAAF Rules, 1949), this definition was focused only on the key concept of ground contact. In 1955, the rule has been divided into two pieces:

> (i) Definition. Walking is progression by steps so taken that unbroken contact with the ground is maintained. (ii) Judging. Judges of walking must be careful to observe that the advancing foot of the walker must make contact with the ground before the rear foot leaves the ground, and in particular, that during the period of each step in which a foot is on the ground, the leg

shall be straightened (i.e., not bent at the knee) at least for one moment (IAAF rule 45,1 and 2 in 1955) (IAAF Rules, 1955).

In 1972, the previous rule was developed to be:

Walking is progression by steps so taken that unbroken contact with the ground is maintained. At each step, the advancing foot of the walker must make contact with the ground before the rear foot leaves the ground. During the period of each step when a foot is on the ground, the leg must be straightened (i.e. not bent at the knee) at least for one moment, and in particular, the supporting leg must be straight in the vertical upright position (IAAF rule 191,1in 1972) (IAAF Rules, 1973), as the straight knee in the vertical upright position was added to this rule.

Ultimately, in 1995, the rule was developed to be: "Race Walking is a progression of steps so taken that the walker makes contact with the ground so that no visible (to the human eye) loss of contact occurs. The advancing leg shall be straightened (i.e. not bent at the knee) from the moment of first contact with the ground until the vertical upright position" (IAAF rule 230,1 in 1995) (IAAF Rules, 1995). This rule contained two obvious changes. The first was the continuously straight leg from the moment of first contact with the ground until in the vertical upright position, but the straightened leg requirement was only needed in the vertical upright posture at the previous rule. The second was maintaining contact as viewed by the human eye as double support no longer has to be observed as in the previous rule but instead undergoes a flight phase (visible or not). Thus, the 1995 rule change resulted in altered racewalking techniques (Hoga et al., 2006).

Osterhoudt indicated that modification that requires knee straightening at the rule after 1995 was a great mistake because this rule dramatically increases the prospect of “loss of contact”. He concluded that the current rule has caused more tragedy and should be repealed, while the previous rule should be reintroduced and strictly enforced (Osterhoudt, 2000). Unlike what Hanly (2014) proved in another study that the kinematics of the knee during late stance may therefore demonstrate significant assistance in limiting vertical displacement of the center of mass and revealing a hitherto unnoticed benefit of the straightened knee to effective race walking that may help minimize obvious loss of contact (Hanley, 2014). Through a personal interview with a group of experts (coaches - racewalkers - judges), their opinions differed, as some of them preferred the stage A rule, others preferred the stage B rule, and others were hesitant. From the previous presentation, it is noted that necessary to know the most appropriate and clear rules for judges is required so that they can make their arbitral decisions in an easier and more meaningful way. Also, knowing the most efficient and effective rules for athletes in terms of maintaining technique at high speeds is needed.

To our knowledge, no studies have been conducted on the impact of racewalking rules updates on elite athletes’ performance, eligibility, and nations' classification. Our analysis can expand theoretical knowledge to determine the most appropriate rule today and predict the 20 and 50-km athletes’ performance so that those interested in walking events can benefit from it in development.

Thus, our first aim in this paper is to study the impact of the last three racewalking rules updates on elite athletes’ performance, athletes’ eligibility, and nations' classification in Olympics 20 and 50 km (men) between 1956 and 2016, by examining: (i) The differences in the elite athletes’ performance (race times, speed, and BMI) of the 10-best competing; (ii) The differences in athletes’ eligibility (participants in starting line and finishers) and (finishers ratio, withdrawn ratio, and disqualified ratio) % participants in starting line; (iii) The differences in the performance between countries in race walking held worldwide, considering the 5-best nations and 10-best racewalkers competing. Secondly, we aim to investigate the association and regression between performance times of 20, and 50 km events and explanatory variables (BMI, and age).

2. METHODS

2.1. Study Design

This paper was an exploratory and comparative study which used data obtained from an official webpage. Initially, we collected data from the records of the Olympic games of male racewalkers competing in 20km and 50km events between 1956 and 2016. The available data included the athlete’s name, ranking, race time, date of birth, country of birth, year of competition, body mass, and height. The athlete’s age was computed by taking into account the date of birth and the date of the competition (International Olympic Committee, 2022; Olympedia, 2022). The mentioned period (1956 to 2016) was divided into three stages according to the updates of the racewalking rules (Figure 1), as follows: (i) Stage A, which included the Olympic Games from 1996 to 2016 and numbered 6 championships, which were judged according to the IAAF rule 230,1 (in 1995); (ii) Stage B, which included the Olympic Games from 1976 to 1992 and numbered 5 championships for 20km event and 4championships for 50 km event, which were judged according to the IAAF rule 191,1 (in 1972); (iii) Stage C, which included the Olympic Games from 1956 to 1972 and numbered 5 championships, which were judged according to the IAAF rule 45, (1and 2) (in 1955).

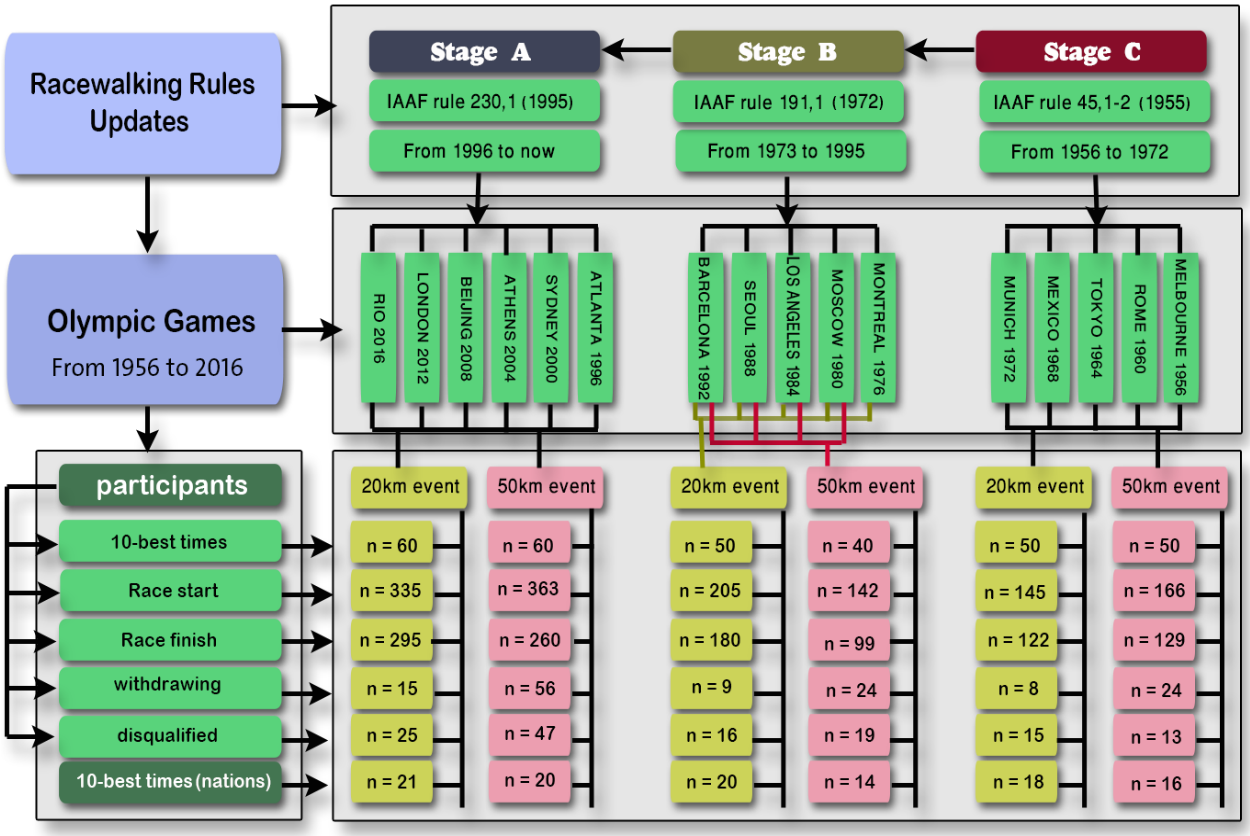

Figure 1. Framework of the three stages (A, B, and C), taken from the Olympic Games between 1956 and 2016 in the 20km and 50km events

This study was approved by the Ethics committee of the computers and information faculty at Mansoura University (code 202205020). Since the study involved the analysis of publicly available data, the requirement for informed consent was waived.

2.2. Participants

The sample in this study included 310 elite racewalkers, who were in the top 10 times in an Olympic 20km and 50km between 1956 and 2016. The top 10 times were recommended based on previous studies (Knechtle et al., 2022; Seffrin et al., 2021). Participants were divided into three groups according to the three stages (A, B, and C) of the racewalking rules (Figure 1). The participants' descriptions ARE presented in (Table 1).

Table 1. Anthropometric data of the racewalkers (mean ± SD) and CV in the top 10-times in each event according to the three stages (A, B, and C) of the racewalking rules

Stages	Event	n	Age (year)		Height (cm)		Mass (kg)		BMI (Kg/m^2)	
			Mean ± SD	CV	Mean ± SD	CV	Mean ± SD	CV	Mean ± SD	CV
stage A	20 km	60	26.27 ± 4.24	16.13	175.75 ± 6.37	3.63	62.78 ± 5.55	8.85	20.33 ± 1.59	7.82
	50 km	60	29.17 ± 4.28	14.68	177.10 ± 6.32	3.57	64.17 ± 5.83	9.08	20.43 ± 1.13	5.55
stage B	20 km	50	27.72 ± 4.60	16.59	176.36 ± 7.22	4.10	65.92 ± 6.39	9.70	21.17 ± 1.32	6.21
	50 km	40	29.23 ± 5.33	18.25	175.45 ± 7.10	4.04	64.43 ± 5.09	7.91	20.93 ± 1.09	5.19
stage C	20 km	50	28.90 ± 4.69	16.23	179.80 ± 3.73	2.07	69.18 ± 5.44	7.87	21.41 ± 1.66	7.76
	50 km	50	29.42 ± 4.73	16.09	177.52 ± 5.57	3.14	67.00 ± 5.64	8.42	21.25 ± 1.37	6.45
Total	20 km	160	27.54 ± 4.60	16.70	177.21 ± 6.21	3.14	65.76 ± 6.34	9.64	20.93 ± 1.60	7.62
	50 km	150	29.27 ± 4.70	16.06	176.80 ± 6.31	3.57	65.18 ± 5.69	8.73	20.84 ± 1.25	6.00

Note: n = sample size; CV = coefficient of variation; BMI = Body Mass Index; CV ranged from 2.07 to 18.25 %, less than 30 %, which indicates the homogeneity of the research sample.

2.3. Statistical Analysis

IBM SPSS Statistics version 26.0 software as a computer-aided software system is utilized, which had a significant role in interpreting the results and their derivatives to handle and analyze the outputs accurately and with high efficiency in this paper. Descriptive data were presented by the arithmetic mean, standard deviation (SD), coefficient of variation (CV), Maximum (MAX), and Minimum (MIN) values. The data normality distribution was tested by the Kolmogorov–Smirnov and Shapiro-Wilk tests. To verify the relationship of updates in race walking rules on the athletes' performance, in the mentioned three stages (A, B, and C), the mean values of the results for the top 10-time participants were selected, then we calculated both walking speed and BMI in both events (20 and 50 km). The non-parametric Kruskal–Wallis test was used to verify differences between groups, given that 20km time and walking speed did not present a normality distribution. While the differences regarding the 50 km time, walking speed, and BMI and 20km BMI using post hoc Bonferroni test and Dunnett T3 were used to verify differences between groups. To observe differences in the participants' eligibility, we used the number of participants at the starting line as well as those who finished the race. Also, we calculated (the finishers ratio, the withdrawn ratio, and the disqualified ratio) % participants at the starting line in both events (20km and 50km) **(**Figure 1). To observe the differences in the performance by nations, we adopted the nations of the top 10 time racewalkers classified in Olympic games in countries with at least 4 racewalkers in the ranking, countries with less than 4 athletes in the ranking were excluded. Effect sizes were calculated as partial eta-squared values ($\eta 2$) and determined as small ≥ .08, medium ≥, .20, and large ≥ .32 (Cohen, 1992). Change ratio ($\Delta\%$) was used to verify differences between groups. A multiple linear regression model for performance prediction was used between BMI and age as explanatory variables in both events (20km and 50km) and times as dependent variables. A significance level of $p \leq 0.05$ was taken for all results reported.

3. RESULTS

In the current study, we presented the major findings according to the explained procedures and statistical analysis in the previous subsections. The participants included 310 elite racewalkers, who were top 10 times in an Olympic 20km and 50km between 1956 and 2016. The 20 km included 160 racewalkers with a (Mean ±SD, Min-Max) race speed of (3.89± .26, 3.37-4.23 m/sec), age (27.54 ± 4.60, 19-41 years), and BMI (20.93 ± 1.60, 17.04-27.34 Kg/m2). The 50 km included 150 racewalkers with a (Mean ±SD, Min-Max) race speed of (3.47± .29, 2.7-3.84 m/sec), age (29.27 ± 4.70, 20-42 years), and BMI (20.84 ± 1.25, 17.31-24.22 Kg/m2.

3.1. The differences between stages (A, B, and C) in the elite racewalkers' Performance of the 10-best competing in Olympics 20 and 50 km.

The results showed in Olympic 20km a significant difference between stages (A, B, and C) favoring stage A in (race time and athletes' speed) with a large effect size, where (H=126.67, P .000 < .05, η2= .826) for race time and (H=86.69, P .000 < .05, η2= .54) for athletes' speed (Tables 2). While BMI was favored to stage A with a small effect size, where (F=6.65, P .002 < .05, η2= .078) (Table 3).

In addition, there was a significant difference in Olympic 50km between stages (A, B, and C) favoring stage A in (race time and athletes' speed) with a large effect size, where (F=210.1, P .000 < .05, η2= .741) for race time and (F=244.8, P .000 < .05, η2= .769) for athletes' speed. While BMI was favored to stage A with medium effect size, where (F=6.46, P .002 < .05, η2= .081) (Table 3).

Table 2. The differences and Δ% between stages (A, B, and C) in the elite racewalkers' performance (race times, athletes' speed) of the 10-best competing in the Olympic 20 km.

Variable	stage	n	Mean ± SD	Mean Rank	H	P-value	η2	Differences: stages	Z	P-value	Mean Rank	Δ%
Time (min) 20km	A	60	80.37 ± .86	34.12	126.67	**.000***	.826	A-B	-9.01	**.000***	34.12 - 81.16	**A < B = 5.96**
	B	50	85.16 ± 3.19	82.76				A-C	-7.7	**.000***	30.50 - 85.50	**A < C = 14.1**
	C	50	93.52 ± 3.06	133.90				B-C	-8.06	**.000***	27.10 - 73.90	**B < C = 9.82**
speed (m/sec) 20km	A	60	4.06 ± .23	115.41	86.69	**.000***	.54	A-B	-5.23	**.000***	70 – 38.1	**A > B = 1.97**
	B	50	3.98 ± .14	85.82				A-C	-7.36	**.000***	75.91 – 31.01	**A > C = 12.5** **B > C = 9.3**

C	50	3.61 ± .15	33.29		B-C	-7.83	**.000***	73.22 - 27.78

Note: *. The mean difference is significant at the .05 level.

Table 3. The differences and Δ% between stages (A, B, and C) in the elite racewalkers' performance (race times, athletes' speed, and BMI) in the Olympic 50 km and BMI in 20km of the 10-best competing.

Variable	n	stage	Mean ± SD	Min - Max	F	*p*	η2	Differences			Δ%
								stages	B	C	
Time (min) 50 km	60	A	224.8 ± 3.64	216.9 - 231.9	210.1	**.000***	.741	A	**-10.15***	-43.09*	**A < B = 4.54**
	40	B	235 ± 9.28	218.5 - 256.4				B		-32.94*	**A < C = 18.8**
	50	C	267 ± 17.2	236.2 - 308.6							**B < C = 13.6**
speed (m/sec) 50 km	60	A	3.71 ± .06	3.59 - 3.84	244.8	**.000***	.769	A	**.156***	.585*	**A > B = 4.31**
	40	B	3.55 ± .14	3.25 - 3.81				B		.429*	**A > C = 18.9**
	50	C	3.12 ± .2	2.70 - 3.53							**B > C = 12.1**
BMI (Kg/m^2) 50 km	60	A	20.43 ± .2	17.31 - 22.53	6.46	**.002***	.081	A	-.496	-.82*	**A < B = 2.44**
	40	B	20.93 ± 1.09	18.81 - 22.88				B		-.324	**A < C = 3.86**
	50	C	21.25 ± 1.37	18.62 - 24.22							**B < C = 1.53**
BMI (Kg/m^2) 20 km	60	A	20.33 ± 1.59	17.04 - 27.34	6.65	**.002***	.078	A	-.578	-1.07*	**A < B = 2.97**
	50	B	20.99 ± 1.25	17.10 - 23.38				B		-.494	**A < C = 4.98**
	50	C	21.49 ± 1.54	17.53 - 24.30							**B < C = 2.38**

3.2. The differences between stages (A, B, and C) in the participants' eligibility

To compare stages (A, B, and C) in the participants' eligibility, we collected the participants at the starting line, finishers, withdrawn, and disqualified (Figure 2). Then (the finish ratio, the withdrawn ratio, and the disqualified ratio) % of the participants were collected at the starting line in both events (20 and 50) km.

Regarding the number of participants, there were observed significant differences in Olympic 20km between stages (A, B, and C) favoring stage A with a large effect size, where (F=14.57, P .000 < .05, η2= .691) for the participants in the starting line, and (F=15.43, P .000 < .05, η2= .741) for the finishers (Table 4). Also, there were observed significant differences in Olympic 50km favoring stage A with large effect size, where (F=16.34, P .000 < .05, η2= .731) for the participants in the starting line (Table 4) and (H=10.233, P .000 < .05, η2= .731) for the finishers (Table 5).

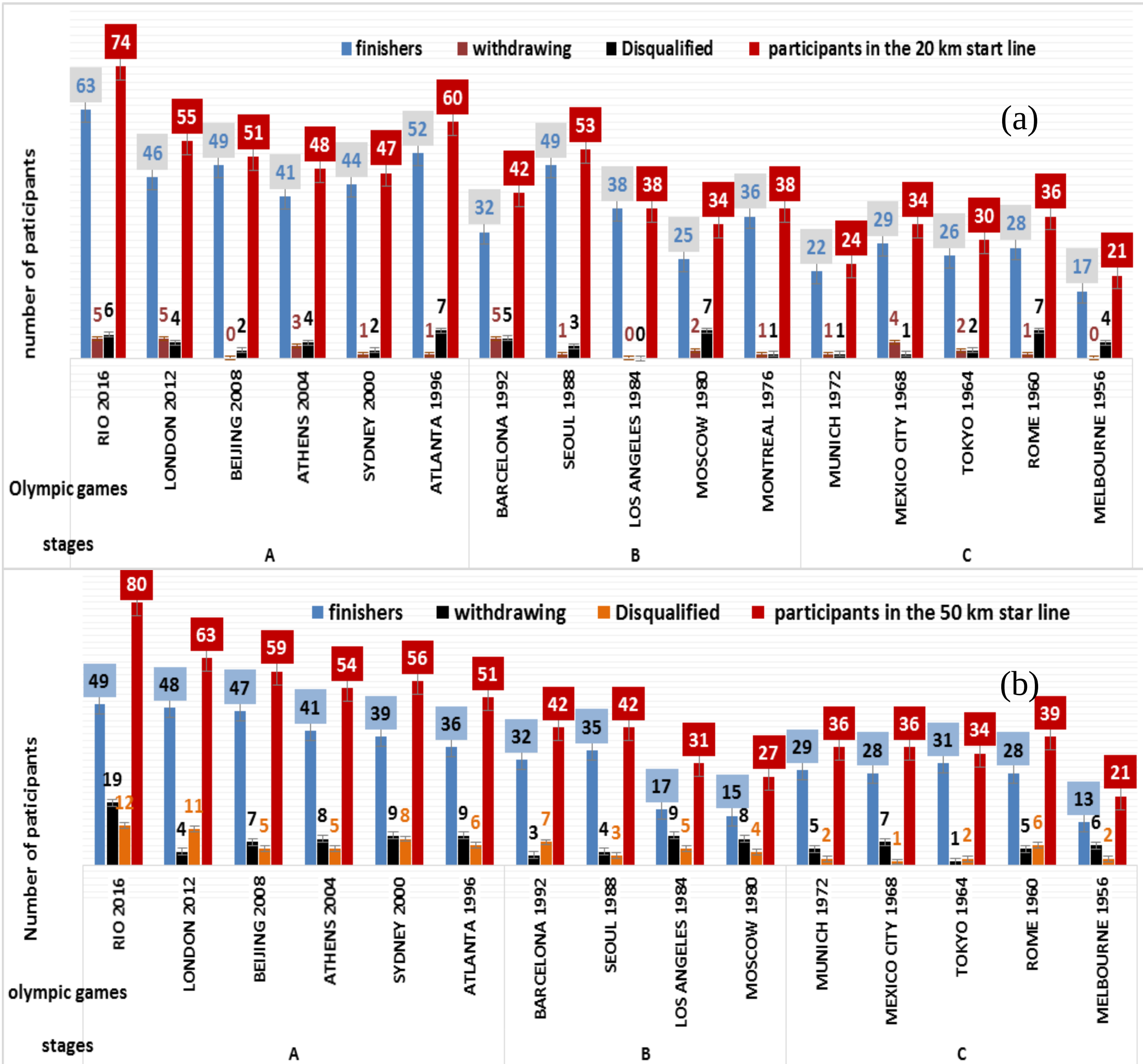

Figure 2. The sum of participants who were on the starting line, the finishers, the withdrawn, and the disqualified; (a) Olympic 20km, (b) Olympic 50km.

Table 4. The differences and Δ% between stages (A, B, and C) in the number of participants (in the starting line and finishers) at the 20km and (in the starting line) at the 50km.

Variable	n	stage	Mean ± SD	Min - Max	F	P-value	η2	Differences			Δ%
								stage	B	C	
The participants in the 20km starting line	6	A	55.83 ± 10.1	47 - 74	14.57	**.000***	.691	A	14.8*	26.8*	**A >B = 36.17** **A >C = 92.51** **B >C = 41.38**
	5	B	41 ± 7.28	34 - 53				B		12*	
	5	C	29 ± 6.4	21 - 36							
The finisher (20 km)	6	A	49.16 ± 7.78	41 - 63	15.43	**.000***	.741	A	13.17*	24.78*	**A >B = 36.56** **A >C = 101.4** **B >C = 47.54**
	4	B	36 ± 8.8	25 - 49				B		11.6	
	5	C	24.4 ± 4.92	17 - 29							
The participants in the 50km starting line	6	A	60.5 ± 10.41	51 - 80	16.34	**.000***	.731	A	25*	27*	**A < B = 70.42** **A < C = 82.23** **B < C = 6.93**
	4	B	35.5 ± 7.68	27 - 42				B		2.3	
	5	C	33.2 ± 7.05	21 - 39							

Table 5. Δ% between stages (A, B, and C) in the number of finishers at 50km.

Variable	stage	n	Mean ± SD	Mean Rank	H	P-value	η2	Differences: stages	Z	P-value	Mean Rank	Δ%
The finisher (50 km)	A	6	43.33 ± 5.39	12.50	10.233	**.006***	.636	A-B	-2.56	.011*	7.5 - 2.5	**A >B = 75.07**
	B	4	24.75 ± 10.21	5.50				A-C	-2.75	.006*	8.5 - 3	**A >C = 67.95**
	C	5	25.80 ± 7.25	4.60				B-C	-.492	.623	5.5 - 4.6	**B < C = 4.07**

*. The mean difference is significant at the .05 level. n = Olympic participations size

Regarding the participants' ratio % (Table 6), there was a significant improvement in Olympic 20km between stages (A, B, and C) favoring stage A, where Δ%= [(A > B) =1.2, (A > C) = 4.68 and (B > C) = 3.45] for the finisher ratio. Also, there was a significant improvement between stages (A, B, and C) favoring stage A, where Δ%= [(A < B) = 3.21, (A < C) = 14.96, and (B < C) = 12.14] for withdrawn ratio. In addition, there was a significant improvement between stages (A, B, and C) favoring stage A, where Δ%= [(A < B) = 3.21, (A < C) = 14.96, and (B < C) = 12.14] for withdrawn ratio. In addition, there was a significant improvement between stages (A, B, and C) favoring stage A, where Δ%= [(A < B) = 10.98, (A < C) = 30.55, and (B < C) = 21.98] for disqualified ratio.

Table 6. Δ% between stages (A, B, and C) in the participant's ratio (the finisher ratio, withdrawn ratio, and disqualified ratio) % at the 20 and 50km.

			Distance: 20 km		50 km	
Variable	n	stage	Mean ± SD	Δ%	Mean ± SD	Δ%
finishers ratio %	6	A	88.43 ± 5.13	A > B = 1.2	72.21 ± 6.55	**A > B = 7.01**
	5	B	87.38 ± 11.8	A > C = 4.68	67.48 ± 14.47	**A < C = 5.78**
	5	C	84.47 ± 5.35	B > C = 3.45	76.64 ± 10.82	**B < C = 11.95**
withdrawn ratio %	6	A	4.32 ± 3.55	A < B = 3.21	15.08 ± 5.82	**A < B = 19.78**
	4	B	4.46 ± 4.45	A < C = 14.96	18.8 ± 12.17	**A < C = 2.89**
	5	C	5.07 ± 4.67	B < C = 12.14	15.53 ± 9.40	**B > C = 21.05**
disqualified ratio %	6	A	7.26 ± 2.88	A < B = 10.98	12.70 ± 3.5	**A < B = 7.16**
	5	B	8.16 ± 8.24	A < C = 30.55	13.68 ± 4.43	**A > C = 62.4**
	5	C	10.45 ± 8.14	B < C = 21.98	7.82 ± 4.86	**B > C = 74.9**

Note: ratio % the participants in the starting line; n = Olympic participations size

3.3. The differences in the performance between countries

To compare the performance of the countries that participated in the male 20, and 50 km race walking events, the first 5th nations that were most often among the top 10 were first selected. The other countries were grouped into a single group called "Others". To observe differences in the performance by nations, we adopted the nations with at least 4 racewalkers in the ranking, countries with less than 4 athletes were excluded (Table 7).

Table 7. The sum of nationality in the top 10 times in each stage

rank	Distance											
	20 km						50 km					
	stage A		stage B		stage C		stage A		stage B		stage C	
	Nationality	**n (%)**	**Nationality**	**n (%)**	**Nationality**	**n (%)**	**Nationality**	**n (%)**	**Nationality**	**n (%)**	**Nationality**	**n (%)**
1st	China Australia	8 (13.3) 8 (13.3)	Italy	10 (20)	Germany Britain	9 (18) 9 (18)	Poland	9 (15)	Spain	7 (17.5)	Germany Britain	8 (16) 8 (16)
2nd	Russia	7 (11.7)	Germany Mexico	7 (14) 7 (14)	Ukraine	6 (12)	China Australia Russia	6 (10) 6 (10) 6 (10)	Germany	6 (15)	Italy	7 (14)
3rd	Spain	5 (8.3)	Spain	5 (10)	Australia Sweden	4 (8) 4 (8)	Spain Mexico	5 (8.3) 5 (8.3)	Russia Mexico	4 (10) 4 (10)	USA Sweden	4 (8) 4 (8)
4th	Italy Ecuador	4 (6.7) 4 (6.7)	Canada	3 (6)	USA	3 (6)	Japan	3 (5)	Italy Slovakia Sweden	3 (7.5) 3 (7.5) 3 (7.5)	Russia	3 (6)
5th	Germany Mexico	3 (5) 3 (5)	Russia Colombia Slovakia	2 (4) 2 (4) 2 (4)	Mexico Russia Italy	2 (4) 2 (4) 2 (4)	Italy Canada France Ireland Latvia Norway Slovakia	2 (3.3) 2 (3.3) 2 (3.3) 2 (3.3) 2 (3.3) 2 (3.3) 2 (3.3)	Australia Belarus Finland	2 (5) 2 (5) 2 (5)	Australia Kazakhstan Mexico Canada Hungary Luxembourg	2 (4) 2 (4) 2 (4) 2 (4) 2 (4) 2 (4)
Others	(13 nations)	18 (10.8)	(12 nations)	12 (24)	(9 nations)	9 (18)	(6 nations)	6 (10)	(4 nations)	4 (5)	(4 nations)	4 (8)
total	21 nations	60	20 nations	50	18 nations	50	20 nations	60	14 nations	40	16 nations	50

n = nations size (%) = nations ratio % total nations

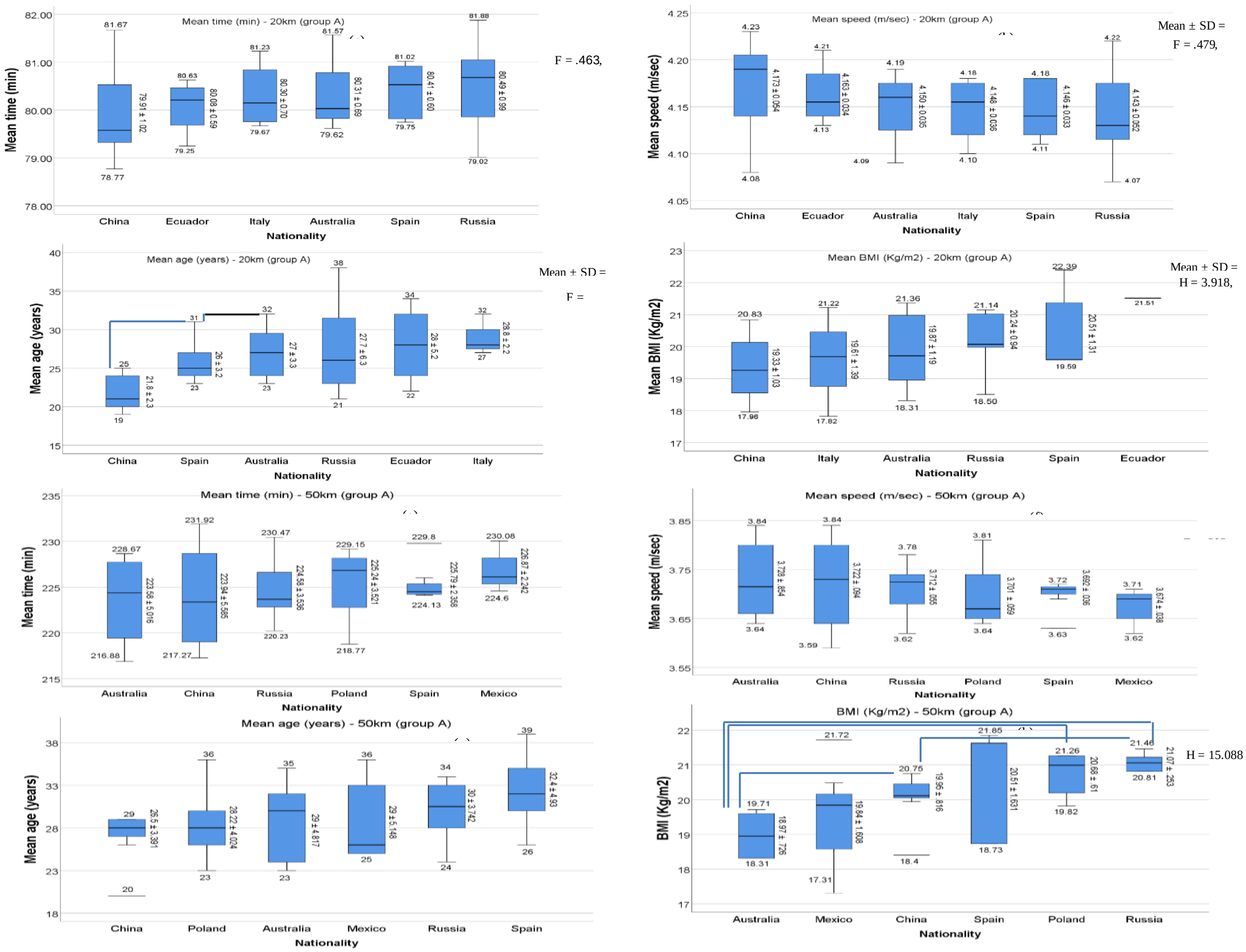

Figure 3. Mean race times, speed, age, and BMI and significant differences among nationalities, regarding group A (20km and 50km). * p <.05.

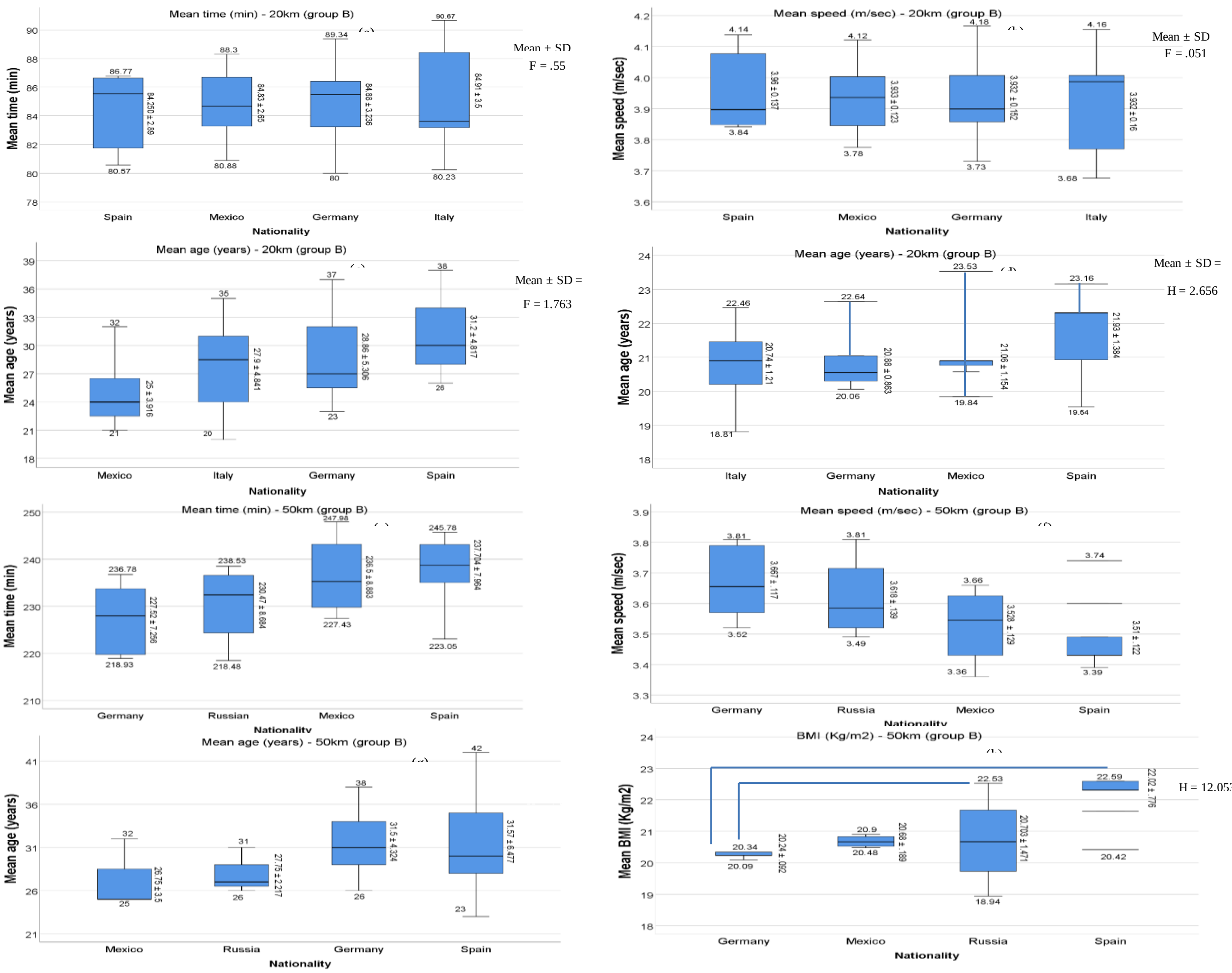

Figure 4. Mean race times, speed, age, and BMI and significant differences among nationalities, regarding group B (20km and 50km). * p <.05.

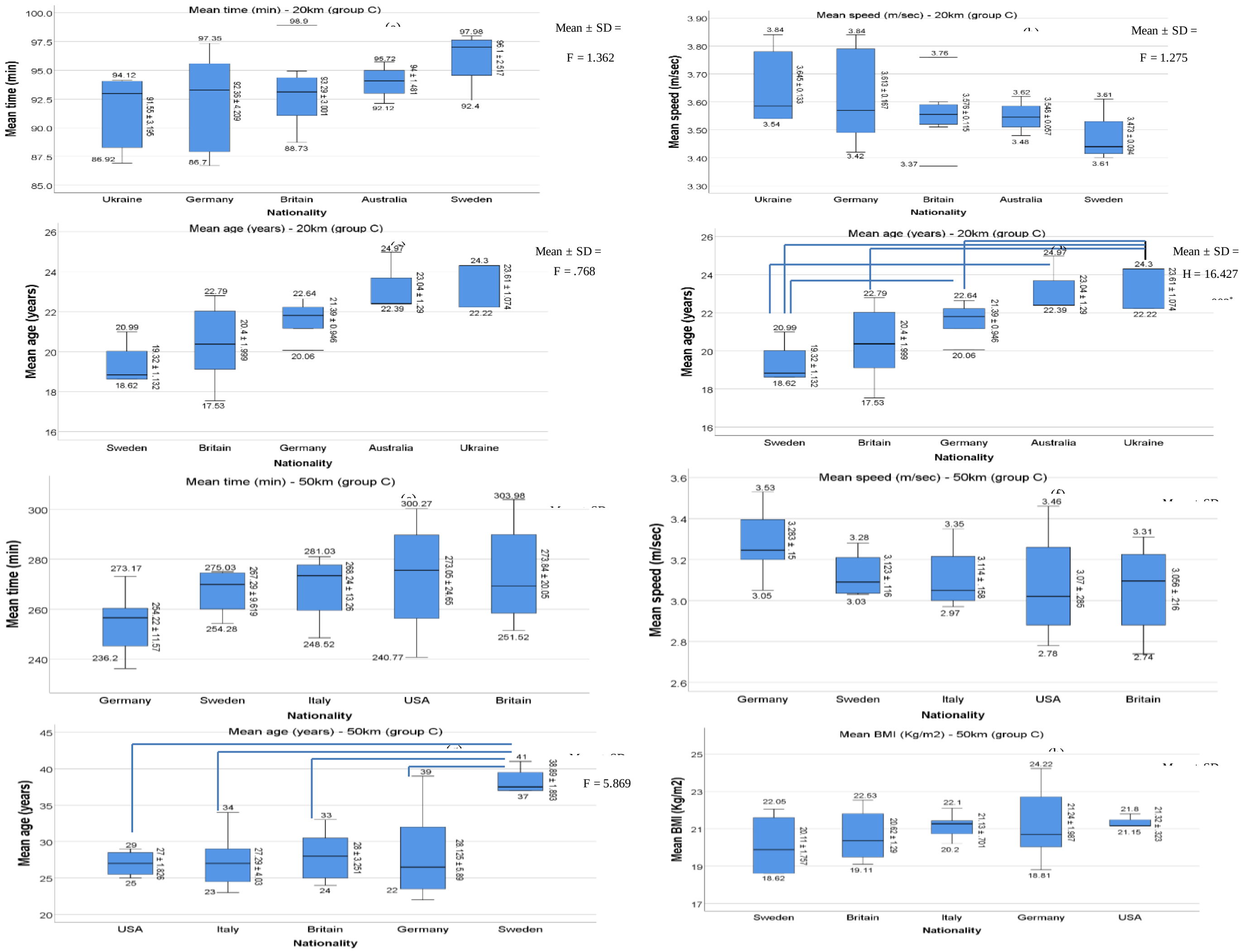

Figure 5. Mean race times, speed, age, and BMI and significant differences among nationalities, regarding group C (20km and 50km). * p <.05.

Regarding nationality, for stage A in the 20 km event, there were observed no significant differences in the average time [F = .463, p = .801] (Figure 3a), mean speed [F = .479, p = .789] (Figure 3b) and mean BMI [H = 3.918, p = .417] (Figure 3d). On the other hand, there was a significant difference in the age [F = 2.679, p = .041*, η2=.309] (Figure 3c). While in the 50km event, there were no significant differences in the average time [F = .522, p = .758] (Figure 3e), mean speed [F = .505, p = .77] (Figure 3f), and mean age [F = 1.148, p = .356] (Figure 3h). On the other hand, there was a significant difference in mean BMI [H = 15.088, p = .010*, η2=.363] (Figure 3g).

Regarding nationality, for stage B, in the 20 km event there were observed no significant differences in the average time [F = .55, p = .982] (Figure 4a), mean speed [F = .051, p = .984] (Figure 4b), mean the age [F = 1.763, p = .180] (Figure 4c) and mean BMI [H = 2.656, p = .448] (Figure 4d). While in the 50km event, there were no significant differences in the average time [F = 2.093, p = .139] (Figure 4e), mean speed [F = 2.05, p = .145] (Figure 4f), and mean the age [H = 4.872, p = .181] (Figure 4g). On the other hand, there was a significant difference in mean BMI [H = 12.053, p = .007*, $\eta 2$=.529] (Figure 4h).

Regarding nationality, for stage C in the 20 km event, there were observed no significant differences in the average time [F = 1.362, p = .273] (Figure 5a), mean speed [F = 1.275, p = .304] (Figure 5b) and mean the age [F = .768, p = .556] (Figure 5c). On the other hand, there was a significant difference in mean BMI [H = 16.427, p = .002*, $\eta 2$=.551] (Figure 5d). While in the 50km event, there were no significant differences in the average time [F = 1.724, p = .175] (Figure 5e), mean speed [F = 1.728, p = .174] (Figure 5f) and mean BMI [H = 1.88, p = .598] (Figure 5h). On the other hand, there was a significant difference in mean age [F = 5.869, p = .002*, $\eta 2$=.474] (Figure 5g).

3.4. Regression results between time and (BMI and age) in both events (20km and 50km)

To find out the relationship between time and (BMI and age), a multiple linear regression model was used in which BMI and age were considered explanatory variables and times as dependent variables (Table 8).

Table 8. Regression results between time and (BMI and age) in both events (20km and 50km)

Dependent variable	n	Independent variables	R p-value	B p-value	B constant	R	R^2	F p-value	VIF
20 km race time	160	BMI	.279 P= .000	.981 P= .001	58.219 P= .000	.343	.118	10.465* P= .000	1.009
		Age	.225 P= .002	.262 P= .009					
50 km race time	150	BMI	.235 P= .002	4.334 P= .003	164.744 P= .000	.254	.065	5.075* P= .007	1.013
		Age	-.068 P= .002	-.45 P= .232					

The results of the regression model demonstrated that there was a significant relationship between time and explanatory variables where (B constant =58.219, P .000) for 20km race time and (B constant =164.744, P .000) for 50km race time.

4. DISCUSSION

This study investigated the impact of the last three modifications in racewalking rules on elite athletes' performance, athletes' eligibility, and nations' classification in Olympics 20 and 50 km (men) between 1956 and 2016. In addition, the prediction of races times in terms of BMI and age was considered. The following are major achievements:

- The impact of stages (A, B, and C) on the elite racewalkers' Performance of the 10-best competing in Olympics 20 and 50 km.

In the present study, we found a significant difference between stages (A, B, and C) favoring stage A in race time and athletes' speed with large effect sizes for both races. In addition, stage A achieved the highest percentage of improvement in the performance of the elite race walkers (race time and athletes' speed) % in both races than the other stages, where Δ (race time, athletes' speed) % was represented as (A < B = 5.96 and A < C = 14.1, A > B = 1.97, A > C = 12.5) % for 20km and (A < B = 4.54 and A < C = 18.8, A > B = 4.31, A > C = 18.9) % for 50 km. This indicates that the current rule (stage A) after 1995 is better in the athletes' performance than the previous rules.

- The impact of stages (A, B, and C) on the participants' eligibility.

It is noted that there is an increase in the number of participants at the starting line and the finishing places in both races in favor of stage A with a large ES. Also, stage A achieved the lowest withdrawn ratio % followed by stage C and stage B achieved the biggest value in the 50km race, where Δ% was (A < B = 19.78, A < C = 2.89, and B > C = 21.05). While stage A achieved the lowest withdrawn ratio % followed by stage B and stage C achieved the biggest value in the 20km race, where Δ% was (A < B = 3.21, A < C = 14.96, and B < C = 12.14). The results indicate that most of the participants had the efficiency and the ability to finish the race with the least percentage of withdrawals under the current rule compared to other previous rules.

On the other hand, stage C achieved the lowest disqualified ratio %, followed by stage A and stage B achieved the biggest value in the 50 km race, where Δ% was (A < B = 7.16, A > C = 62.4 and B > C = 74.9). While stage A achieved the lowest disqualified ratio % followed by stage B and stage C achieved the biggest value in the 20km race, where Δ% was (A < B = 10.98, A < C = 30.55, and B < C = 21.98). Thus it can be interpreted to the inexperienced judges in stage C, while the number of disqualified in stage (A) decreased and increased in stage (B) in both events. This indicates that the current rule has helped judges to make their arbitral decisions in an easier and more meaningful way compared to the previous rules. All the above indicates that the current rule currently is the best for the racewalkers and the most accessible and effective for the judges' subjective judgments.

- The impact of stages (A, B, and C) on the Nations' Classification of the 10-best competeing in Olympics 20 and 50 km.

During the period after 1956 and before 1972 (stage C) when the top 10 in the 20 km were considered, the largest number of participants were from Germany and Britain, followed by walkers from Ukraine, Australia, and Sweden. The Ukrainian walkers were the fastest among the 18 participating countries, followed by Germany, Britain, Australia, and Sweden, respectively. Ukrainians were the oldest contestants with the highest value in BMI and Swedes were the youngest among the countries mentioned with the lowest BMI. While in the 50 km, Germany and Britain achieved the largest number of participants, followed by walkers from Italy, America, and Sweden. The German walkers were the fastest among the 16 participating countries, followed by the Russians, Mexicans, and Spaniards, respectively. Swedes were the oldest participants, followed by Germans, and Americans were the youngest. Americans have the highest BMI, followed by Germans, and Swedes have the lowest BMI.

During the period after 1972 and before 1995 (stage B), when the top 10 in the 20 km were considered, the largest number of participants were from Italy, followed by Germany, Mexico, and then Spain. The Spanish were the fastest walkers among the 20 participating countries, followed by Mexicans, Germans, and Italians, respectively. Spanish walkers were the oldest and the highest in BMI. While in the 50 km, Spain achieved the largest number of participants, followed by Germany, then Russia and Mexico. The Germans were the fastest contestants among the 14 participating countries, followed by the Russians, Mexicans, and Spaniards, respectively. The Spaniards were the oldest, followed by the Germans, and the Mexicans were the youngest. The Germans also had the lowest BMI and the Spaniards the highest.

During the period after 1995 to the present time when the top 10 in the 20 km were considered, China and Australia achieved the largest number of participants, followed by Russia, Spain, Italy, and Ecuador, respectively. The Chinese were the fastest among the 21 participating countries, winning their walkers, followed by Ecuador, Australia, Italy, Spain, and Russia, respectively. The Chinese participants were the youngest and had the lowest BMI compared to the other countries. While in the 50 km, Poland achieved the largest number of participants, followed by China, Australia, and Russia. The Australians are the fastest among the 20 participating countries, their walkers won, followed by the Chinese, then Russia, Poland, Spain, and Mexico, respectively. The Chinese walkers were the youngest, followed by the Poles and the Australians. Australians were the lowest in the BMI, followed by the Mexicans and Chinese, respectively.

The previous discussion shows the importance of BMI and age and their clear impact on the speed and performance of elite walkers after the 1995 rule (stage A). Where there was a significant impact of the current rule on the racewalking technique. This led to the emergence of new countries for the first time on the scene such as China, Poland, and Ecuador, whose competitors were younger and lower in BMI compared to the rest of the countries. Germany, Mexico, Britain, Ukraine, and Sweden emerged on the scene under the previous rules (stages B and C) and disappeared under the current rule (stage A). Other countries, such as Spain, Australia, Italy, and Russia are maintaining their presence in the three rules (A, B, C).

After the 1995 rule, China flourished and grew up on the scene in the walking race events, clearly, and it was the country with the greatest number of participants from the top 10 and the fastest walkers in the 20 km. In addition, the Chinese achieved second place in the number of participants from the top 10 and the second-fastest walkers in the 50 km. On the other hand, Australia ranked first in the number of participants and the third-fastest walkers in the 20 km Olympics. In addition to the second place in the number of participants from the top 10 and the fastest walkers in the 50 km. These previous results in the ranking of countries indicate that excellence in racewalking is not the result of chance or the bias of the judges, but rather is due to the good preparation of the contestants through well-thought-out plans and clear goals that are achieved by the factors leading to winning (building a broad base of contestants - providing the necessary capabilities to spread culture and practice as many as possible Of the contestants - availability of qualified trainers and experts as well as standard sports equipment) taking into account the younger age and lower BMI of the contestants as shown in Table 1 and Figure3, 4, and 5.

- Prediction of 20 and 50km Races Times using Age and BMI

There was a significant relationship between time and explanatory variables where (B Constant =58.219, P .000) for 20km race time and (B Constant =164.744, P .000) for 50km race time (Table 9). The explanatory variables explain 11.8% of variations in 20km time and 6.5% of variations in 50km time showing that the strength of the relationship between time and the explanatory variables is moderate. By referring to the F value where (F=10.465, P .000) for 20km race time and (F=5.075, P .007) for 50km race time, it may be concluded that the model is valid and there is a correlation between time and the explanatory variables. To verify the existence of the mentioned relationship, a multi-collinearity test was carried out. The results revealed the VIF of the model was $1.009 < 3$ for 20km race time and $1.013 < 3$ for 50km race time indicating the non-existence of a multi-collinearity problem.

So, we indicated that the equations (1 & 2) can be used for race time prediction. The researchers attributed the finding of these equations to the correlation between the BMI and age with 20 and 50km races times, which formed the basis for inferring a predictive relationship between them.

$$\text{Predicted (20 km race time)} = 58.219 + .981 * \text{BMI} + .262 * \text{age} + \text{error} \quad (1)$$

$$\text{Predicted (50 km race time)} = 164.744 + 4.334 * \text{BMI} + -.45 * \text{age} + \text{error} \quad (2)$$

Where B Constant, BMI, Age = 58.219, .981, .262 for 20km and 164.744, 4.334, -.45 for 50km, respectively. There are other intelligent techniques, e.g., artificial intelligence, deep learning, and machine learning, which can be used for prediction (Elshewey et al., 2023).

Finally, this study agreed with the Hanley study (2014) in that elite athletes were able to satisfy the straightened knee rule without negatively impacting their great speeds. Also, the knee's kinematics during late stance has been proven to be a useful aid in reducing vertical displacement of the center of mass, and revealing an advantage of the straightened knee to efficient race walking that might also help prevent visible loss of contact (Hanley, 2014). We do not agree with the Osterhoudt study in which it was suggested that the current rule governing race walking has brought further misfortune and should be abolished (Osterhoudt, 2000).

The current rule is considered the most appropriate at present, which is commensurate with the sequential increment in the number of participants and their current speeds. We advise the countries that emerged on the scene previously and disappeared with the current rule and the other countries that are interested in participating in the events of the walking race to pay attention to the selection and training of walkers who have the skill, speed and good style with a small age and less BMI. Whereas the results of this study proved that the elite walkers who are the lowest in age and the lowest in BMI are the fastest and most efficient walkers in our time (stage A).

5. CONCLUSIONS

In this paper, we investigated the impact of the last three modifications in racewalking rules on elite athletes' performance, athletes' eligibility, and nations' classification in Olympics 20 and 50 km (men) between 1956 and 2016, in addition to investigating the regression between performance times of 20, and 50 km events and explanatory variables (BMI, and age). The results indicated that the current rule after 1995 is better for the athletes' performance than the previous rules. Also, it is indicated that most of the participants had the efficiency and the ability to finish the race with the least percentage of withdrawals under the current rule compared to other previous rules. The results also proved that the elite walkers who are the lowest in age and the lowest in BMI are the fastest and most efficient walkers in our time. All the above indicates that current rule is the best for the racewalkers and the most accessible and effective for the judges' subjective judgments. We believe in the future, with the steady increase in the number and speeds of contestants and the tremendous scientific progress in the field of technology and artificial intelligence, technology will be used to detect the contestants' mistakes and at that time the judgment will be easier and more efficient, and the controversy over the racewalking ends once and for all. So, Machine learning and deep learning are recommended to enhance the performance of racewalkers under the current rule.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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