Maximum aerobic speed, maximum oxygen consumption, and running spatiotemporal parameters during an incremental test among middle- and long-distance runners and endurance non-running athletes

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Background. Maximal aerobic speed (MAS) is a useful parameter to assess aerobic capacity and estimate training intensity in middle- and long-distance runners. However, whether middle- and long-distance runners reach different levels of MAS compared to other endurance athletes with similar $\dot{V}O_{2max}$ has not been previously studied. Therefore, we aimed to compare $\dot{V}O_{2max}$, MAS and spatiotemporal parameters between sub-elite middle- and long-distance runners (n = 6) and endurance non-runners (n = 6). In addition, we aimed to compare the maximal blood lactate concentration [BLa] experienced by participants after conducting these tests. **Methods.** Telemetric portable respiratory gas analysis, contact and flight time, and stride length and rate were measured using a 5-m contact platform during an incremental test at a synthetic athletics track. $\dot{V}O_2$, heart rate, respiratory quotient values in any 15 s average period during the test were measured. [BLa] was analyzed after the test . Running spatiotemporal parameters were recorded at the last two steps of each 400 m lap. A coefficient of variation (%CV) was calculated for each spatiotemporal variable in each participant from 8 km·h⁻¹ onwards. **Results.** Whereas runners reported faster MAS(21.0 vs. 18.2 km·h⁻¹) than non-runners(p=0.0001, ES = 3.0), no differences were found for $\dot{V}O_{2max}$ and maximum blood lactate concentration during the running tests (p > 0.05). While significant increases in flight time and stride length and frequency (p < 0.001, $0.52 \leq \eta_p^2 \leq 0.8$) were observed throughout the tests, decreases in contact time (p < 0.001, η_p^2 = 0.9) were reported. Runners displayed a greater %CV (p = 0.015) in stride length than non-runners. We conclude that middle- and long-distance

runners can achieve a faster MAS compared to non-running endurance athletes despite exhibiting a similar $\dot{V}O_{2max}$. This superior performance may be associated to a greater mechanical efficiency. Overall, runners displayed a greater ability to modify stride length to achieve fast speeds, which may be related to a more mechanically efficient pattern of spatiotemporal parameters than non-runners.

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5 **Running head**: Maximum aerobic speed in runners

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21   ABSTRACT

22   **Background.** Maximal aerobic speed (MAS) is a useful parameter to assess aerobic capacity

23   and estimate training intensity in middle- and long-distance runners. However, whether middle-

24   and long-distance runners reach different levels of MAS compared to other endurance athletes

25   with similar VO_{2max} has not been previously studied. Therefore, we aimed to compare VO_{2max},

26   MAS and spatiotemporal parameters between sub-elite middle- and long-distance runners (n = 6)

27   and endurance non-runners ($n = 6$). In addition, we aimed to compare the maximal blood lactate

28   concentration [BLa] experienced by participants after conducting these tests.

29   **Methods.** Telemetric portable respiratory gas analysis, contact and flight time, and stride

30   length and rate were measured using a 5-m contact platform during an incremental test at a

31   synthetic athletics track. VO_2, heart rate, respiratory quotient values in any 15 s average period

32   during the test were measured. [BLa] was analyzed after the test. Running spatiotemporal

33   parameters were recorded at the last two steps of each 400 m lap. A coefficient of variation

34   (%CV) was calculated for each spatiotemporal variable in each participant from 8 km·h⁻¹

35   onwards.

36   **Results.** Whereas runners reported faster MAS (21.0 vs. 18.2 km·h⁻¹) than non-

37   runners ($p = 0.0001$, ES = 3.0), no differences were found for VO_{2max} and maximum blood

38   lactate concentration during the running tests ($p > 0.05$). While significant increases in flight

39   time and stride length and frequency ($p < 0.001$, $0.52 \leq \eta_p^2 \leq 0.8$) were observed throughout the

40   tests, decreases in contact time ($p < 0.001$, $\eta_p^2 = 0.9$) were reported. Runners displayed a greater

41   %CV ($p = 0.015$) in stride length than non-runners. We conclude that middle- and long-distance

42   runners can achieve a faster MAS compared to non-running endurance athletes despite exhibiting

43   a similar VO_{2max}. This superior performance may be associated to a greater mechanical

44 efficiency. Overall, runners displayed a greater ability to modify stride length to achieve fast

45 speeds, which may be related to a more mechanically efficient pattern of spatiotemporal

46 parameters than non-runners.

47

48 **KEYWORDS** (5): spatiotemporal parameters; maximal oxygen uptake; maximal aerobic

49 speed; performance; running

50

52   INTRODUCTION

53   Maximal aerobic speed (MAS) is considered a useful parameter to predict performance, test

54   training progression and prescribe and program training in middle- and long-distance runners

55   (Billat et al., 1994b; McLaughlin et al., 2010; Saunders et al., 2004). MAS is defined as the

56   minimum running speed necessary to attain maximal oxygen uptake (vVO_{2max}) during an

57   incremental treadmill running test (Billat et al., 1994b, 1994a; di Prampero et al., 1986).

58   MAS can also be estimated in the field by employing an incremental track running test (Leger &

59   Boucher, 1980).

60   On the other hand, running spatiotemporal parameters can also be related to performance in

61   highly trained and elite distance runners (Moore at al., 2016). They are typically characterized by

62   a more reduced vertical oscillation (Moore et al., 2014), longer stride (Cavanagh & Williams,

63   1982) and shorter ground contact time than those displayed by runners of lesser performance

64   level (Mooses et al., 2021). Whereas endurance athletes need to develop metabolic-related

65   abilities such as VO_{2max}, distance runners also need to be able to apply great forces onto the

66   ground in short times to achieve high running speeds such as MAS. The latter ability is not a

67   requirement of swimmers, cyclists, or rowers. The foot only can apply force onto the ground to

68   displace the body forward during the running ground contact phase. Runners can reach faster

69   speeds through the application of greater forces onto the ground rather than moving the legs at a

70   faster rate (Weyand et al., 2000). In addition, the increase in running speed demands the

71   application of more force during the same contact time or even shorter (de Ruiter et al., 2016)

72   and this is the reason why running speed should be the same when comparing contact times and

73   force application magnitudes among different runners. Stride frequency and length depend on

74   each other and determine running speed. A greater ground reaction force on its vertical and

75   horizontal components to achieve a faster speed while keeping the contact time constant or

76   shorter would result in either an increased stride length, frequency or both. Interestingly, high

77   correlation values have been found between 100 m performance and that in 5000 m and 10,000

78   m in elite long-distance runners (Yamanaka et al., 2020), therefore showing how the ability to

79   apply high levels of ground reaction force on its vertical and horizontal components to achieve

80   high speed is related to running performance. In this way, while VO_{2max} can be improved using

81   any kind of endurance training (i.e., running, swimming, or cycling) (Rosenblat et al., 2022),

82   running MAS improvement requires of specific running training methods to be developed

83   (González-Mohíno et al., 2016).

84   By contrast, it was reported in well-trained subjects that adding alternative training as a

85   complement to running can improve running performance, although not to the same extent as

86   when achieving the same training load through exclusively running (Foster et al., 1995).

87   However, whether middle- and long-distance runners reach different levels of MAS compared

88   with other endurance athletes (i.e., non-runners) with similar VO_{2max} has not been previously

89   studied. Understanding the mechanisms by which a greater running performance is achieved

90   through a similar physiological ability (i.e., VO_{2max}), which in turn may be related to the

91   behavior of spatiotemporal parameters, may be useful for coaches and practitioners to optimize

92   their running training methods.

93   Therefore, the aims of this study were: 1) to compare MAS, VO_{2max} and maximum capillary

94   blood lactate concentration achieved during an incremental track running test between a group of

95   runners and other of non-running endurance athletes; and 2) to compare running spatiotemporal

96   parameters during the test between both groups, in order to establish an eventual relationship

97   between mechanical efficiency indicators and the achievement of MAS. We hypothesized that

98   $\dot{V}O_{2max}$ would not differentiate the runners from non-runners given that both groups were

99   previously exposed to endurance training which represents a suitable stimulus to improve

100 $\dot{V}O_{2max}$. Furthermore, we expected that runners displayed a faster MAS than non-runners also

101 explained by their greater ability to deliberately modify their running spatiotemporal patterns as

102 long as the speed increases due to the lack of specific running adaptations in non-runners.

103 Therefore, their MAS, and not their $\dot{V}O_{2max}$, would be the determining factor of their greater

104 running performance.

105

106 MATERIAL AND METHODS

107 Participants

108 Twelve male athletes of National level participated in the study: six middle- and long-distance

109 runners (runners), and six endurance non-running athletes (non-runners: cycling, n = 1;

110 orienteering, n = 1; triathlon, n = 2, rowing, n = 1; canoeing, n = 1). Their characteristics are

111 summarized in Table 1. Furthermore, regarding the track performance of the six runners, one

112 athlete had completed the 5,000 m and 10,000 m in 14:20 and 29:30 (min:s), respectively, three

113 other athletes had covered the 1,500 m in 3:43.56, 3:45.48 and 3:54.89 (min:s), respectively, and

114 other runners had run the 800 m in 1:50.32 and 1:55.24 (min.s), respectively, at recent

115 competitions. The sample size was calculated to be a minimum of six athletes per group (see

116 Statistical analysis).

117 Athletes were informed of the aims and characteristics of the study and signed their prior consent

118 to participate according to the Declaration of Helsinki. The study was approved by the Ethics

119 Committee for Clinical Research of the Sports Administration of Catalonia (EICAEC

120 10022012).

121

122   ***Table 1***

123

124   Procedures

125   The participants completed an incremental protocol to determine their MAS.

126   After a standard warm-up (10-min run at 60% of MAS and 5 min of dynamic

127   stretching exercises), under an air temperature of 16-18 ºC, relative humidity of 85-90%, and

128   wind velocity < 2 m·s^{-1} measured through GAO-ANEMO-101 (Gaotek, USA), participants

129   performed the Université de Montréal track test (UMTT) (Leger & Boucher, 1980) to assess

130   their individual MAS. The UMTT started at 7 km·h^{-1}, and speed was increased by 2 km·h^{-1} every

131   minute up to volitional exhaustion or inability to maintain the paced speed (García-Pinillos et al.,

132   2019). The test was performed on a synthetic 400 m athletics track and paced by an assistant

133   riding a bicycle equipped with a calibrated digital speedometer.

134   Before, during, and after the test, cardiorespiratory and pulmonary gas exchange parameters

135   were telemetrically recorded using a breath-by-breath portable gas analyzer (K4 b^2, Cosmed,

136   Italy). The instrument was calibrated before each test according to the manufacturer's

137   instructions. Oxygen uptake ($\dot{V}O_2$), heart rate, respiratory quotient values during the last 30 s of

138   the test or when plateau was reached were taken as $\dot{V}O_{2max}$, HR_{max}, and RQ_{max}, respectively.

139   Running spatiotemporal parameters were determined using a 5-m contact platform (Ergo-Runner

140   Bosco System, Italy) located before the finish line. Stride frequency (steps per

141   second), stride length (m), contact time (ms), and flight time (ms) were recorded at

142   the last two steps of each 400 m lap. The participants were instructed to not accelerate on the

143   five-meter contact platform area. A coefficient of variation (%CV) was calculated for each

144   spatiotemporal variable in each participant from 8 km·h⁻¹ onwards to determine the extent to

145   which participants modified each parameter throughout the test to adapt to its increasing speed

146   until exhaustion.

147   Capillary blood lactate concentration was measured on 20 µl samples by a photoenzymatic

148   method (Photometer 4020, Hitachi, Japan) using Boehringer Mannheim (Germany) lactate

149   reagents at rest and 1-, 3-, 5-, 7- and 10-min post-test. The highest value observed among the six

150   [BLa] assessments per test was recorded.

151

152   Statistical analysis

153   Sample size was calculated based on pilot MAS measurements (t-test for two independent

154   samples: $\alpha = 0.05$, power $1-\beta = 0.95$, $d = 0.5$), which yielded a minimum of 6 subjects per group

155   (actual measurements power $= 0.98$).

156   All analyses were performed with the Statistical Package for Social Sciences 24.0 program

157   (IBM, Armonk, NY, USA). Data are presented as mean ± standard deviation (SD). Normality of

158   data distribution (Kolmogorov-Smirnov test), variance homogeneity (Levene's test), and

159   assumption of sphericity (Mauchly's test) as applicable were checked in all parameters. When the

160   sphericity assumption was violated, the Greenhouse-Geisser correction was used.

161   Spatiotemporal parameters during the MAS test were compared between groups at two running

162   speeds: 8 km·h⁻¹ (V8), and 12 km·h⁻¹ (V12) through Student's t-test for independent samples.

163   Between-stage comparisons were made by repeated measures ANOVA with four intra-

164   subject factors/speeds (i.e., V8, V12, the intermediate speed between V12 and MAS [V12-

165   MAS], and MAS). Partial eta-squared (η_p^2) values were calculated to determine effect sizes and

166   interpreted as follows: trivial (< 0.1), small ($0.01-0.04$), moderate ($0.04-0.11$), large ($0.11-0.20$),

167   or very large (> 0.20). Differences were assessed using the Bonferroni's *post hoc* test. %CV was

168   assessed for each spatiotemporal variable in each participant considering the aforementioned

169   four speeds. %CV, MAS, VO_{2max}, HR_{max}, RQ_{max}, and maximum [BLa] were compared between

170   groups through Student's *t*-test for independent samples. The effect size was assessed using the *d*

171   statistic (Cohen, 1988), which was considered either trivial (*d* < 0.20), small (0.20–0.6),

172   moderate (0.6–1.2), large (1.2–2.0), or very large (2.0–4.0) (Hopkins et al., 2009). The level of

173   significance for all tests was *p* < 0.05.

174

175   RESULTS

176

177   Runners achieved a faster MAS (21.0 vs. 18.2 $km \cdot h^{-1}$) than non-runners, although VO_{2max},

178   HR_{max}, RQ_{max}, and maximum [BLa] was not different between both groups (Table 2).

179   Concerning running spatiotemporal parameters, no differences were found between groups in all

180   parameters at V8 and V12.

181

182   ***Table 2***

183

184   Both groups showed a similar pattern in spatiotemporal parameters throughout the test, in which

185   contact time progressively decreased (*p* < 0.001, η_p^2 = 0.9) (figure 1A), paralleled by a

186   progressive increase in flight time (*p* < 0.001, η_p^2 = 0.8) across phases (0.001 < *p* < 0.021),

187   except for the final phase (between V12-MAS and MAS) in which flight time stabilized (figure

188   1B). In turn, stride frequency and stride length (figures 1C, 1D, respectively) progressively

189   increased during the test (*p* < 0.001, η_p^2 = 0.8 and 0.52, respectively) and across phases (0.001 <

190 $p < 0.035$). %CV of stride length was significantly ($p = 0.015$) greater in runners than non-

191 runners (Figure 1D). %CV of the rest of spatiotemporal parameters were similar between groups.

192

193 ***Figure 1***

194

195 DISCUSSION

196 The main aim of the present study was to elucidate whether a group of trained runners displayed

197 different levels of VO_{2max} and MAS than a group of trained non-runners endurance athletes

198 during an incremental test. In agreement with our previous hypothesis, runners achieved a faster

199 MAS (vVO_{2max}) than non-runners despite displaying a similar VO_{2max} and maximal blood lactate

200 concentration. Runners' stride length patterns were similar between both groups, although

201 runners were able to modify their stride length to a greater extent than non-runners throughout

202 the test in order to achieve a greater MAS, showing a likely a higher running mechanical

203 efficiency than non-runners.

204

205 Therefore, differences between runners and non-runners were not explained by participants'

206 VO_{2max} (or maximum blood lactate concentration) and may be attributed to lower body mass (di

207 Prampero et al., 1996), and greater running mechanical efficiency in runners, particularly at fast

208 speeds, in line with previous studies (Billat & Koralsztein, 1996; Fernández-del-Olmo et al.,

209 2002; Williams & Cavanagh, 1987). The faster MAS of the runners (21.0 vs. 18.2 km·h^{-1}) was

210 associated to a more stable pattern of spatiotemporal parameters, characterized by a greater

211 increase in stride length throughout the tests, indicating a likely greater running mechanical

212 efficiency (Tartaruga et al., 2012; Williams & Cavanagh, 1987). The fact that both VO_{2max} and

213   maximum blood lactate concentration did not differ between groups highlights the great level of

214   endurance performance in both groups and not only in runners. While VO_{2max} is considered one

215   of the most important physiological performance determinants in endurance sports (Foster,

216   1983), the correlation between blood lactate concentration and level of performance in endurance

217   events is very strong (Maffulli et al., 1991; Roecker et al., 1998). However, athletes need to

218   develop other specific sport-related (i.e., running) abilities such as those involving the

219   neuromuscular system to be able to achieve high running speeds.

220

221   Williams and Cavanagh (1987) reported that 54% of the inter-individual variability existing in

222   running economy could be explained by spatiotemporal variables and demonstrated that most

223   economical runners possess a typical running style. Accordingly, running economy (i.e., the cost

224   of running determined through O_2 consumption at a submaximal steady-state intensity) is

225   considered one of the most important physiological performance determinants in distance

226   running (Foster & Lucia, 2007). Interestingly, in a one-case study, Jones (2006) reported that the

227   8% improvement observed in 3000-m performance in an Olympic runner over five years was

228   achieved with a concomitant 10% decrease in VO_{2max} but was associated with MAS

229   improvement. Thus, running performance could be partially explained by mechanical efficiency

230   and capacity to generate greater muscle power (i.e., longer stride length in less time) in a

231   situation of fatigue. Furthermore, adaptations resulting from an increase in running speed also

232   involve specific changes in spatiotemporal parameters such as the observed progressive increase

233   in stride rate, stride length, and flight time, and the progressive decrease in contact time (Figure

234   1). Our results are in line with previous investigations focused on the evolution of spatiotemporal

235   parameters during incremental treadmill running tests (Brughelli et al., 2011; Castro et al., 2013).

236   On the other hand, it has been shown that endurance training decreases the variability in stride

237   frequency, leading to reduced mechanical and energy cost of running (Slawinski & Billat, 2004).

238   These authors assessed these two main factors according to the training status of three groups of

239   athletes (highly, well, and less trained endurance runners). They reported that highly trained

240   runners did not display a lower energy cost of running than runners of lower training status

241   displayed, but a lower mechanical cost of running. Highly trained runners achieved this more

242   efficient running pattern through a reduction in the amplitude of movement of the center of mass.

243   They concluded that running performance might be associated with the same self-optimizing

244   mechanism contributing to a reduction in the impact loads generated during the initial portion of

245   the support phase of the stride (Slawinski & Billat, 2004).

246   The greater variation in stride length adopted by runners than non-runners while not decreasing

247   contact time may be then explained by their more efficient ability to produce a wide range in

248   both vertical and horizontal components of ground reaction forces during a constant contact time.

249   Furthermore, stride frequency did not increase in runners to a greater extent than in non-runners

250   to achieve a faster MAS. It has been reported that the ability to select an optimal stride length or

251   stride frequency depends on the runner's performance level (de Ruiter et al., 2014). This optimal

252   running pattern of spatiotemporal parameters which is achieved through a self-optimization

253   process can be assessed through the acute manipulation of either stride frequency or length so

254   that a curve is derived mathematically to set their most economical levels (de Ruiter et al., 2014).

255   Typically, the optimal stride length is within a range between 3% longer to shorter than the

256   preferred one (Connick & Li, 2014; de Ruiter et al., 2014) and variations of this magnitude

257   cannot modify the running economy (Moore et al., 2014). However, greater variations than 6%

258   in either stride length or frequency would incur in a further deterioration of running economy (de

259   Ruiter et al., 2014). In this sense, novice runners reported a greater variation in their preferred

260   stride frequency from their optimal stride frequency (i.e., 8%) than that in experienced runners

261   (i.e., 3%) (de Ruiter et al., 2014), therefore showing the greater ability of the latter to adequately

262   self-select their preferred stride frequency. These findings are consistent with those of the present

263   study given that the group of runners were able to increase their stride length to properly suit the

264   increasing speed demands of the incremental test and finally achieved a substantial faster MAS

265   than the group of non-runners. Despite kinetic factors were not analyzed in the present study, the

266   greater variation in stride length and faster MAS in runners than non-runners while variation in

267   contact and flight times and stride frequency throughout the tests, and all spatiotemporal

268   variables at 8 and 12 km·h^{-1}, and VO$_{2max}$, remained similar among groups, demonstrate that

269   runners may possess a greater ability to apply force onto the ground than non-runners. According

270   to the synergistic approach to understand the metabolic costs associated to running developed by

271   Arellano and Kram (2014), both vertical and horizontal forward forces which are responsible for

272   supporting body weight and accelerating the body, respectively, are the cause for most of the

273   running metabolic cost. In this way, Støren et al. (2011) reported that the sum of both peak

274   vertical and anterior-posterior forces highly inversely correlated with running economy and 3 km

275   performance in elite distance runners. Therefore, experienced and trained runners and more

276   specifically those belonging to the runners' group of the present study may have learnt to

277   decrease the forces applied onto the ground while maintaining running speed. For example, a

278   lower braking was associated to a greater running economy (Lieberman et al., 2015). In addition,

279   the spring-mass model has been proposed to understand the body's bounce during the ground

280   contact phase, given that the magnitude of the ground reaction forces in running are proportional

281   to the body's vertical displacement as if the leg acted as a spring during the contact time

282   (Cavagna et al., 1988; Dalleau et al., 1998; Moore, 2016). Within this context, the concept of

283   stiffness is related to the degree of deformation (i.e., vertical displacement) of the whole body or

284   a part of it (e.g., legs) in relation to the vertical ground reaction force (Butler et al., 2003; Divert

285   et al., 2005). Leg stiffness highly correlates with running economy (Dalleau et al., 1998) and is

286   related to the ability in runners to apply greater ground reaction forces in shorter contact times

287   (Morin et al., 2007). Therefore, runners might have increased their stride length to a greater

288   extent than non-runners due to their supposedly greater leg stiffness. All the aforementioned

289   abilities and adaptations leading to a more refined pattern of spatiotemporal parameters can be

290   achieved through specific running training as well as other types of strength-related training

291   (Blagrove et al., 2018).

292

293   Future studies may focus on the assessment and comparison of kinetic characteristics such as

294   ground reaction forces and leg stiffness among well-trained distance runners and non-running

295   endurance athletes. Some limitations must be acknowledged in the present study First, the lack of

296   running economy analysis, which may have differentiated runners and non-runners and linked

297   those differences to the ones found in spatiotemporal parameters and MAS. Second, the lack of

298   kinetic analysis, which would have explained the causes to a greater extent of the relationship

299   between the greater variation in stride length and faster MAS observed in the group of runners.

300   And finally, a greater sample size would have improved the quality of the statistical analysis.

301

302   CONCLUSIONS

303   These results demonstrate that middle- and long-distance runners can achieve a faster MAS

304   compared to endurance athletes from other modalities, despite exhibiting a similar VO_{2max} and

305   maximum blood lactate concentration. This superior performance may be associated to a greater

306   mechanical efficiency. Overall, at the range of speeds measured, the group of runners exhibited a

307   greater variation in stride length across the tests leading to a faster MAS, which may be related to

308   a more mechanically efficient pattern of spatiotemporal parameters.

309

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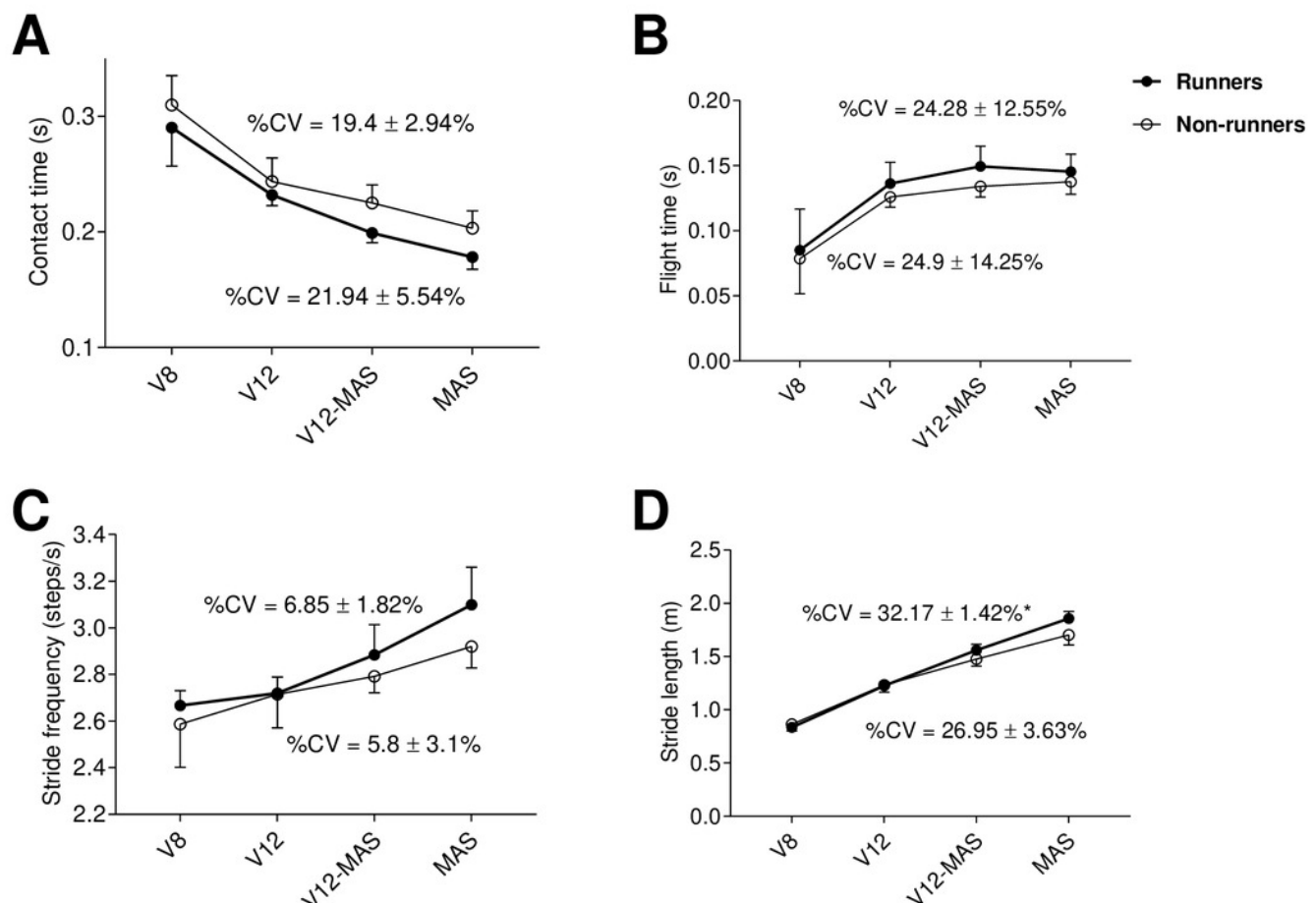
Figure 1

Evolution of kinematic parameters during the maximum aerobic speed (MAS) test for both groups: contact time (A), flight time (B), stride frequency (C), and stride length (D) for each running speed.

*Significant difference ($p < 0.05$) between runners and non-runners in %CV (coefficient of variation). V8: 8 km·h^{-1}; V12: 12 km·h^{-1}; V12-MAS: intermediate speed between 12 km·h^{-1} and MAS.

Characteristics of the two groups of participants. Data are mean (standard deviation).

1 **Table 1.** Characteristics of the two groups of participants. Data are mean (standard deviation).

	Age (years)	Height (cm)	Body mass (kg)
Runners (n = 6)	26.5 (4.0)	176.0 (3.6)	66.7 (0.8)
Non-runners (n = 6)	23.8 (1.7)	180.5 (4.1)	73.1 (4.8)
Differences (p)	0.145	0.061	0.007

Maximum aerobic speed (MAS), $\dot{V}O_{2max}$, maximum heart rate (HR_{max}), respiratory quotient (QR_{max}) and Maximum blood lactate concentration (Lac_{max}), in runners and non-runners.Mean (SD), significance of the differences

*Differences between R and NR groups ($p < 0.05$).

1 **Table 2.** Maximum aerobic speed (MAS), VO_{2max}, maximum heart rate (HR_{max}), respiratory

2 quotient (QR_{max}) and Maximum blood lactate concentration [BLa], in runners and non-

3 runners. Mean (SD), significance of the differences (p), and group effect size (d) are displayed.

	Runners	Non-runners	Significance (p)	Effect size (d)
MAS ($km \cdot h^{-1}$)	21.0 (0.6)	18.2 (1.2)*	0.0001	3.0
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	71.6 (5.4)	78.3 (8.8)	0.14	0.9
HR_{max} ($beats \cdot min^{-1}$)	194 (3)	189 (12)	0.33	0.5
RQ_{max}	1.07 (0.2)	1.03 (0.4)	0.55	0.1
Maximum [BLa] ($mmol \cdot l^{-1}$)	13.6 (1.5)	12.3 (3.7)	0.42	0.5

4 *Differences between R and NR groups ($p < 0.05$).