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Longitudinal analysis of the competitive performance of medal-winning duathletes over a 42-week season

Análise longitudinal do desempenho competitivo de duatletas medalhistas ao longo de uma temporada de 42 semanas

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Abstract – Duathlon is a modality considered recent that consists of running-transition-cycling-transition-running and still lacks scientific informations about the competition system that helps in the preparation of athletes. Therefore, the objective was to analyze the competitive performance of duathletes based on anthropometric, neuromuscular and physiological indicators throughout six stages of the competition. For this purpose, seven male duathletes medalists in their respective categories (39.5 ± 4.9 years, 73.9 ± 8.7 kg and 63.7 ± 6.5 VO2max) who participated throughout the six stages in 42 week-season of the Interior Cup were analyzed. The following were analyzed total and partial time (hh:mm:ss), average speed (km/h), pace (mm:ss), body mass (kg), body fat (%), vertical jump (watts and cm), heart rate (bpm), lactate (mmol-L-1) in addition to geographic and climatic conditions. In the main results, there is a significant difference in the time and average speed throughout the six stages, with the best results in stages three and five (S3 and S5). The values of vertical jump are significantly lower after the race, while lactate concentration is significantly higher. It is hypothesized that this work may benefit coaches and duathletes from the characterization of the modality carried out through the analysis of long-term competitive performance that highlights the relevance of some particularities of the sprint duathlon, mainly regarding the importance of the calendar, regulations and rules of the competition, in addition to the influence of geographic and climatic conditions on the final performance of the athlete.

Key words: Task performance and analysis; Competition; Cycling; Running.

Resumo – *Duathlon é uma modalidade considerada recente que consiste em corrida-transição-ciclismo-transição-corrida e ainda carece de informações científicas sobre o sistema de competição, que auxiliem na preparação de atletas. Portanto, o objetivo foi analisar o desempenho competitivo de duatletas com base em indicadores antropométricos, neuromusculares e fisiológicos ao longo de seis etapas da competição. Para tanto, foram analisados sete duatletas do sexo masculino (39,5 ± 4,9 anos, 73,9 ± 8,7 kg e 63,7 ± 6,5 VO2máx) que participaram das seis etapas ao longo de 42 semanas da Copa Interior e foram medalhistas em suas respectivas categorias. Foram analisados tempo total e parcial (hh:mm:ss), velocidade média (km/h), pace (mm:ss), massa corporal (kg), gordura corporal (%), salto vertical (watts e cm), frequência cardíaca (bpm), lactato (mmol-L-1), além das condições geográficas e climáticas. Nos principais resultados há diferença significativa no tempo e na velocidade média ao longo das seis etapas, com os melhores resultados nas etapas três e cinco (S3 e S5). Os valores de salto vertical são significativamente menores após a corrida, enquanto a concentração de lactato é significativamente maior. Hipotetiza-se que este trabalho pode beneficiar treinadores e duatletas a partir da caracterização da modalidade realizada por meio da análise do desempenho competitivo de longo prazo que evidencie a relevância de algumas particularidades, principalmente quanto à importância do calendário, regulamentos e regras da competição, além da influência das condições geográficas e climáticas no desempenho final do atleta.*

Palavras-chave: *Análise de desempenho de tarefas; Competição; Ciclismo; Corrida.*

INTRODUCTION

Duathlon is a cyclic modality, which obtains energy through aerobic-anaerobic metabolism and is composed of running-transition-cycling-transition-running[1]. It appeared in the mid-1980s and since then, there has been an exponential increase in practitioners and competitions at different levels mainly in the sprint and Olympic distances[2].

Therefore, knowing the characteristics of the modality and analyzing competitive performance based on different indicators becomes important and can help guide adequate sports preparation, which, in turn, is understood as a complex process composed of three systems: competition, training and support[3]. For this, it is necessary to understand the competitive activity and the factors that compose it and can influence the result such as: actions and specific biomotor skills, calendar, weather conditions, among others[4]. In this way, data collected in the field during a competition can bring science closer to coaches, contributing in a useful and significant way[5].

Thus, the competitive performance analysis can contribute to the athlete's development, directing the training, identifying aspects associated with the achievement of positive results and, determining models of the competitive activity[6,7]. In duathlon, this information still seems limited, resulting in a scenario that makes the use of references from other modalities, making the proper process of sports preparation difficult. Therefore, the objective of this work was to analyze and compare the competitive performance of amateur duathletes based on kinanthropometrical indicators throughout a competition season. It is hypothesized that this work can benefit coaches and athletes based on the characterization of the modality performed through the analysis of long-term competitive performance.

METHOD

This research is longitudinal (Figure 1) and has a quantitative approach. Seven male duathletes (39.5±4.9 years, 73.9±8.7 kg, 16.0±4.9% body fat) who were preparing for a Regional Cup participated in the study and were medalists in their respective categories. The inclusion criteria were: experience in state-level competitions for at least two years, having finished among the age group's top three in the previous two years, having no injuries in the analyzed period, participate in all stages of the competition, use the road-type bicycle and having signed the Free and Informed Consent Form. The study was approved by the Research Ethics Committee of the State University of Campinas under protocol number 00348818.1.0000.5404.

Study design

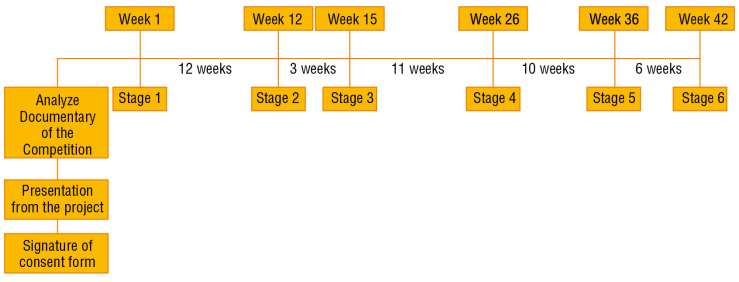

Figure 1. Study design.

The classification of Regional Cup was based on the sum of points, with S2 and S4 worth double points. The competition follows the rules and regulations of the "Brazilian Triathlon Comitee". The sprint distance consisted of 2.5 km run (R1), transition (T1), 20 km cycle (Cyc), transition (T2) and 5 km run (R2). Collections were performed at the same time of day by the same evaluators at all stages.

One limitation of monitoring street competitions is the lack of mastery over some particularities that can influence the results. Among them, it is possible to highlight: i) geographic conditions – (elevation gain, average slope and peak slope); ii) weather conditions (average temperature, rainfall and air humidity).

Competitive performance indicators

The information provided by the organization of the race were: total time, partial times R1, Cyc and R2 and final classification. The partials of each segment were verified using GARMIN® watches, as well as the average speed (km/h) and pace (mm:ss) of R1, Cyc and R2.

Anthropometric indicators

The variables collected were mass (kg) and body fat (%BF) through skinfold analysis[8]. A scale with a precision of 10 grams expressed in kg (Toledo®2098) and an adipometer (PrimeMed® – precision 1mm) were used. No type of physical exercise was performed in the 24 hours preceding.

Neuromuscular indicators

The vertical jump test (VJ) with countermovement (CMJ) was used without the aid of the arms on a contact mat (CEFISE® - JumpSystem1.0®) five minutes before the beginning and right after the end of the competition. The athletes performed a standardized warm-up of 15 minutes of easy running. Three attempts were performed with an interval of ten seconds each and only the one with the highest value was used[9]. The variables considered were power (watts) and jump height (cm).

Physiological indicators

The heart rate (HR) was checked using a monitor for each athlete (GARMIN®935). The following data were collected: resting HR (HRr), average (HRav), maximum (HRmax) and the behavior of the HR in each segment. To analyze the lactate concentration, 20 microliters (µl) of blood were collected from the ear (Accusport®). The evaluations were performed before - seated for 15 minutes - and after the competition - immediately after crossing the finish line.

Geographical and Climatic Conditions

The information used regarding climatic and geographic conditions is available on the event's official website[10] (Chart 1).

Chart 1. Geographic and climatic conditions according to segments and competition stages.

Conditions		Segment	Competitions Stages (S)					
			1	2	3	4	5	6
Geographics	Elevation gain (m)	Run 1	34.7	46.0	23.6	33.5	46.0	23.6
		Cycling	310.0	248.0	174.0	345.0	147.0	174.0
		Run 2	90.7	78.7	51.4	83.6	48.7	51.4
	Average Slope (%)	Run 1	2.8	3.6	1.8	2.5	1.6	1.8
		Cycling	3.7	2.2	1.8	3.2	2.2	1.8
		Run 2	3.6	3.1	2.0	3.2	2.1	2.0
	Slope peak (%)	Run 1	20.3	13.6	4.6	8.6	13.6	4.6
		Cycling	11.7	18.4	5.9	11.8	14.9	5.9
		Run 2	11.7	13.8	6.0	9.0	7.8	6.0
Climatics	Main Temperature (°C)		28.5	26.0	25.3	7.1	27.1	27.9
	Rain (mm/m²)		0	0	0	14	0	0
	Relative humidity (%)		45	48	42	75	51	55

Statistical analysis

The information was processed in a data spreadsheet with the descriptives values. Then, the analysis of variations was used for the one-factor model, complemented with Tukey's test of multiple comparisons, when there was adherence of the data to the normal distribution of probabilities. In the absence of adherence, the Kruskal-Wallis test was used, complemented with the Dun test[11]. All statistical analyzes were performed using the SPSS® software version20 and using a significance level of 5%.

RESULTS

Table 1 shows a difference in the time partials of R1, Cyc and R2 over the six stages, with the smallest appearing in S3 and S5 ($p<0.05$) specifically in Cyc, it is not a high time in S4 in relation to the other five stages ($p<0.01$), which does not occur in the other segments. Therefore, there is a significant decrease in the total time partials (Ttotal) in S3 and S5 in relation to the others.

Table 1. Descriptive statistics of time in each segment, in the six competition stages.

Variable	Competition Stages (S)						Value p
	1	2	3	4	5	6	
T_{R1} (mm:ss)	10:17 (01:22)[a]	10:02 (01:05)[a]	08:46 (01:18)[b]	09:13 (0:31)[a]	08:36 (01:19)[b]	09:48 (01:18)[a]	p<0.05
T_{T1} (mm:ss)	01:20 (00:31)	01:17 (00:33)	01:08 (00:22)	01:19 (00:46)	01:22 (00:31)	01:24 (00:37)	p>0.05
T_{Cyc} (mm:ss)	41:18 (05:16)[bc]	44:08 (05:58)[bc]	36:05 (04:07)[a]	46:38 (05:08)[c]	35:55 (01:23)[a]	38:13 (03:18)[ab]	p<0.01
T_{T2} (mm:ss)	01:27 (00:24)	00:59 (00:20)	01:09 (00:14)	00:55 (00:12)	01:17 (00:34)	01:25 (00:33)	p>0.05
T_{R2} (mm:ss)	23:50 (03:37)[a]	26:00 (03:09)[a]	22:07 (03:00)[b]	24:04 (03:00)[a]	22:02 (04:41)[b]	24:37 (03:52)[a]	p<0.05
T_{total} (hh:mm:ss)	01:19:50 (10:56)	01:23:40 (09:50)	01:10:17 (09:01)	01:21:40 (10:19)	01:09:02 (07:19)	01:15:16 (07:38)	p>0.05

Note: Two averages followed by at least one letter do not different from each other (p>0.05).

Table 2 shows the average values of speed (SPDav) and pace of R1, Cyc and R2, which also present significant differences along the stages, with the best results in S3 and S5. Among these variables, there is an accentuated difference in the values referring to Cyc ($p<0.01$), when compared to R1 and R2 ($p<0.05$).

Table 2. Descriptive statistics of SPDavg and pace of R1, Cyc and R2, in the six competition stages.

Variable	Competitions Stages (S)						Value p
	1	2	3	4	5	6	
SPD^{avg} R1 (km/h)	14.5 (1.9)^{a}	15.0 (1.5)^{a}	17.6 (2.4)^{b}	14.7 (1.7)^{a}	16.3 (0.9)^{b}	15.2 (2.1)^{a}	p<0.05
SPD^{avg} Cyc (km/h)	29.5 (4.3)^{cb}	27.0 (3.2)^{bc}	33.2 (3.7)^{a}	26.2 (3.4)^{c}	33.4 (1.4)^{a}	31.6 (2.6)^{ba}	p<0.01
SPD^{avg} R2 (km/h)	13.3 (2.0)	11.6 (1.3)	13.7 (1.8)	12.8 (1.6)	13.5 (1.5)	12.5 (1.7)	p>0.05
Pace R1 (mm:ss /km)	04:08 (00:33)^{a}	04:00 (00:29)^{a}	03:25 (00:32)^{b}	04:05 (00:12)^{a}	03:41 (00:31)^{b}	03:57 (00:34)^{a}	p<0.05
Pace Cyc (mm:ss /km)	02:05 (00:16)^{ab}	02:13 (00:17)^{ab}	01:49 (00:13)^{a}	02:17 (00:19)^{b}	01:48 (00:07)^{a}	01:54 (00:09)^{ab}	p<0.01
Pace R2 (mm:ss /km)	04:31 (00:45)	05:10 (00:37)	04:23 (00:35)	04:41 (00:36)	04:27 (00:35)	04:47 (00:25)	p>0.05

Note: Two averages followed by at least one letter do not different from each other (p>0.05).

In Table 3, it is not possible to perceive significant oscillation in the values of body mass and %G throughout the competition, as well as in the neuromuscular variables, height and power of the VJ. However, in all stages, the values found after the test indicate a decrease in the height (0.9 to 2.6 cm) and power (150.7 to 826.6 w) of the VJ, in relation to the pre-race moment. These results indicate responses regarding the level of fatigue caused by running the sprint distance.

As for the physiological variables, an increase was observed in the values found after the race (6.7-9.9 mmol-L-1) in relation to the pre-race (2.0-4.3 mmol-L-1), which points to responses regarding the metabolic characteristics of the duathlon. Regarding the average HR values no relevant difference was observed between the six stages.

Table 3. Descriptive statistics of anthropometric, neuromuscular and physiological indicators in the six stages of competition.

Variable	Competition Stages (S)						Value p
	1	2	3	4	5	6	
Body Fat (%)	15.3 (4.4)	14.7 (4.0)	14.5 (4.1)	15.0 (4.6)	14.4 (3.9)	14.3 (3.3)	p>0.05
Body Mass (kg)	73.2 (8.8)	72.1 (8.1)	72.2 (7.6)	73.1 (8.6)	72.5 (8.13)	71.8 (7.8)	p>0.05

Note: Two averages followed by at least one letter do not different from each other (p>0.05).

Table 3. Continued...

Variable	Competition Stages (S)						Value p
	1	2	3	4	5	6	
VJ_{height} (cm) Pre Race	35.1 (4.8)	38.0 (4.5)	37.4 (4.8)	37.1 (5.5)	36.5 (4.7)	34.1 (5.4)	p>0.05
VJ_{height} (cm) Post Race	33.1 (5.3)	35.9 (4.3)	35.4 (3.8)	32.3 (3.2)	33.8 (4.5)	31.4 (2.8)	p>0.05
VJ_{power} (w) Pre Race	3265.3 (423.6)	3604.1 (373.3)	3099.5 (571.6)	3514.1 (377.1)	3101.4 (533.9)	3023.6 (523.4)	p>0.05
VJ_{power} (w) Pos Race	2877.6 (534.0)	3156.8 (167.1)	2948.5 (398.8)	2653.8 (1349.1)	2457.4 (1151.1)	2522.2 (1406.2)	p>0.05
Lactate (mmol-L^{-1}) Pre Race	4.2 (0.4)[b]	2.0 (0.6)[a]	2.1 (0.38)[a]	2.2 (0.7)[a]	2.2 (0.6)[a]	2.3 (0.7)[a]	p<0.01
Lactate (mmol-L^{-1}) Post Race	9.9 (1.0)[b]	7.9 (1.5)[ab]	8.3 (2.3)[ab]	7.4 (0.9)[ab]	6.7 (2.0)[a]	7.2 (2.2)[ab]	p<0.05
HR_{rest} (bpm)	73.2 (4.8)	74.7 (4.1)	73.5 (4.8)	72.8 (6.3)	68.4 (2.9)	69.8 (2.3)	p>0.05
HR_{avg} (bpm)	161.5 (5.8)	168.1 (7.9)	155.5 (18.2)	158.5 (11.4)	160.4 (7.1)	162.2 (6.6)	p>0.05
HR_{max} (bpm)	181.2 (13.1)	193.5 (7.5)	179.2 (18.3)	182.8 (11.4)	182.4 (10.3)	182.8 (12.5)	p>0.05

Note: Two averages followed by at least one letter do not different from each other (p>0.05).

DISCUSSION

Over 42 weeks, the competition takes place outdoors in four different locations. These characteristics are associated with different geographical conditions depending on the location of the test, in addition to the unpredictability of weather conditions. These factors are part of the duathlon's competitive activity, therefore, understanding them becomes fundamental to discuss the performance analysis.

Data referring to performance indicators point to lower values in time and pace in R1, Cyc and R2 in S3 and S5 in relation to the others. At S2 and S4 there is a decrease in the Cyc variables, in addition to a significant difference in the Ttotal of the race. These variations may be related to geographic conditions,

as in S3 and S5, the elevation gain, average slope and peak slope of R1, Cyc and R2, present a lower value when compared to the other stages, allowing a high manifestation of speed and influencing performance[12,13].

In the present study, it is noted that in the stage with the highest competition Ttotal (S2), cycling had the lowest SPDav between stages. Some authors point to the length and inclination of the climbs in cycling as an important aspect in performance and often determines the winner13. In fact, when observing the geographic conditions of S2, it is noticed that the elevation gain is not the greatest however, the peak inclination was 18.4%. Considering that the cycling step consisted of four 5km laps, the effort required to cover such a route is evident, resulting in a high time, showing that the observation of only one variable related to geographic conditions is not feasible in the performance analysis. It is also possible to see in S2 that the performance in R2 may have been influenced by the neuromuscular wear generated by cycling, resulting in the longest time in this segment among all stages. Subsequently, it is observed in S4, the highest value of cycling elevation gain, followed by the rain condition (14 mm/m^2) which interferes with riding the bicycle. Despite the climatic conditions, it is verified in S4 that the variables related to R1, T1, T2 and R2 did not suffer significant changes in relation to the others. The analysis in an integrated way allows us to understand that cycling makes a relevant contribution to the final result in sprint duathlon.

Considering that the athletes in this sample were preparing specifically for this competition, it is predictable that the best results were sought in S2 and S4, which added up to double scores, however, when observing the data of time, speed and pace, can be perceived an apparent performance degradation in these steps. However, all participants were in the same conditions and, the seven athletes finished the stage in the age group's first place. High values in the temporal variables are presented in S6 in relation to S3, even with identical geographic conditions and similar climate, which points to the influence of the regulation, since in S5, the individual classification was already defined for most categories, which leads us to consider that, possibly, the athletes acted in S6 without the objective of seeking the best performance. Therefore, it is understood that the calendar, regulations and rules, in addition to the performance's variables and climatic conditions, can be considered as characteristics of competitive activity in duathlon which is important for the organization of training.

As for anthropometric indicators, studies carried out with ultramarathon runners[14] point out that lower values of body mass and %BF are related to better performance. A study that analyzed 51 amateur street runners found that 86.2% of men have values below 20.9%BF while 68.2% of women have values above 23.1% and that these athletes may have inadequate habits for a good performance[15]. In another study researchers analyzed the %BF in swimmers and indicated 10.8±2.7% (men) and 18.2±3.1% (women) as adequate values for a competitive performance.

In this sense, this study shows that the body mass and %BF values of the duathletes varied between 71.8-73.2 kg and 14.3-15.3%BF, which can be considered satisfactory, since the athletes ended the season in the top three of the competition. Thus, it can be said about the notoriety of the anthropometric indicators in the preparation of duathlon athletes.

With regard to neuromuscular indicators in resistance cycling modalities, specifically in male BMX cycling, values of 50.9±9.7 cm are found in the elite

and 34.1±8.5 cm in amateurs16. In this sense, in the six stages analyzed, values between 34.1-38.0 cm and 3023.6-3604.1 w of pre-race power seem to be in agreement with scores found in amateur athletes of other cyclical modalities. In the post-race a reduction in height (-0.9-2.6 cm) and power (-150.7-826.6 w) of the VJ can be observed. In similar modalities, 10.2±4.5% of reduction in the values of height and power of the VJ after effort indicates moderate to high intensity16. Authors indicate that the analysis of the VJ with lactate concentration can increase the reliability of the data, so that values of eight to 12 mmol-L-1 found after exertion reinforce the indication of accentuated levels of fatigue The athletes analyzed in this sample presented values between 6.7±2.0 mmol-L-1 and 9.9±1.0 mmol-L-1 of lactate concentration along the six stages, reinforcing that the sprint tests duathlon have metabolic characteristics involving the aerobic and anaerobic pathways, which can trigger fatigue installation processes in high percentages[1,16].

Still in the scenario, regarding HR related variables, the data found point to similar values throughout the stages especially in relation to HRav (155±18.2-168.1±7.9 bpm) and HRmax (181.2±13.1-193.5±7.5 bpm), whereas the peaks of HRmax and shown mostly in R2. This information corroborates values found in other investigations carried out with youth athletes of the modality[17] and others such as triathlon and road cycling[12,15].

Within the scope of training methodology, it is known that performance analysis based on a high number of indicators can guide the development of adequate models, minimizing errors in sports preparation. The use of these models is related to the effectiveness of the training, since the importance of standardizing this information is not just a theoretical science, but mainly the application of this knowledge in search of performance[4]. Thus, empirical knowledge can also be included in the process, transforming scientific-experimental works into practical tools to be applied in the daily lives of athletes. Particularly in duathlon, given the problem pointed out regarding the scarcity of works on competitive performance in an integrated and longitudinal way, it seems to be interesting to develop models of competitive activity that consider the history of the modality, the particularities regarding the competitive calendar, rules and in then understanding the use of the kinanthropometrical indicators.

In this way, it is indicated that future investigations about the duathlon analyze, in addition to the indicators pointed out in the present work, information regarding: i) types of bicycles, ii) muscle mass, fat mass, limb length, wingspan and circumferences, iii) cycling cadence, iv) stride frequency in running, v) strategies, between others.

CONCLUSIONS

It is concluded that this work can benefit coaches and duathletes, from the characterization of the modality carried out through the analysis of the long-term performance, highlighting the relevance of some particularities of the sprint duathlon. However, it is important to highlight that duathlon is still a recent modality, which makes it necessary to search for answers of different indicators related to competitive activity. The data from this study can serve as a reference for the elaboration of profiles that compose models of competitive activity, thus allowing the applicability of these data in the preparation of athletes, mainly from the perspective of long-term training.

COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

The project was approved by the Human Research Ethics Committee linked to the State University of Campinas (UNICAMP) under protocol CAEE: 00348818.1.0000.5404.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed the experiments: ATT. Performed the experiments: ATT, AMP, JPB. Analyzed the data: CRP. Contributed reagents/materials/analysis tools: ATT, AMP, CRP, ACG. Wrote the paper: ATT, ACG, JPB.

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