Original Research

The Relationship between Stride Rates, Lengths, and Body Size and their Effect on Elite Triathletes' Running Performance during Competition

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ABSTRACT

Int J Exerc Sci 4(4) : 238-246, 2011. Previous research has suggested that a degree of predictability exists in the relationship between self-selected running stride rates (SR) and stride lengths (SL) with measures of body size such as mass, height and limb lengths. Significant correlations have also been revealed between these body size measures and performance and between SL and performance. However, there is also evidence to suggest that triathlon performance may be related to maintaining a longer SL during the final run. Hence, the aim of this investigation was to examine whether there was any relationship between SR and SL, with body masses and heights of senior elite triathletes during the run stage of a triathlon. The SRs and SLs of 37 male senior elite Triathlon World Championships competitors were analysed via videography and Video Expert II Coach. These values were correlated with the athletes' body masses and heights ($p<0.01$). The results indicated a limited relationship between height and mass with SR in the early stages of the run. However, a significant, positive correlation existed between SL and height at all points from 3 km to the end of the run. Those triathletes who were taller used longer strides. Further research is warranted to examine the effects of cycling on the subsequent run discipline during triathlon and if body size and shape of triathletes have evolved as the young sport of triathlon develops.

KEY WORDS: Performance, cadence, stride length, triathlon, world championships

INTRODUCTION

Triathlon is a sport where three disciplines, swimming, cycling and running, are combined in a continuous manner through two transitions. The importance of the running discipline in draft legal triathlons has become evident in determining final race outcome. Those triathletes, who run faster after cycling and swimming, typically finish in a higher position (1, 20, 21, 22, 28, 30, 38). Thus to enhance overall triathlon performance, one must consider what variables are important in improving run performance at the end of a triathlon.

Previous research suggests athletes spontaneously self-select the most economical frequency of movement in a variety of sports (11, 15, 24, 25, 27, 34, 37). Endurance athletes are no different as they seek an optimal stride rate (SR) and stride length (SL) relationship that allows the greatest sustainable running speed for least effort (3, 6).

However, when comparing to triathlon related research it is evident that prior cycling and swimming has an impact on the SR and SL chosen during final run leg (4, 12, 16, 20). Hausswirth et al., (16) reported a decrease in running SL following cycling with no change in SR. Other researchers have concluded that as fatigue increases during running, SR and SL, characteristics begin to alter, with a decrease in SL, and if running velocity is to be maintained an increase in SR (9, 16, 41). Most triathlon research indicates an increase in the energy cost of running after cycling (8, 14, 16, 19, 26, 29) suggesting an increased level of fatigue at the commencement of the run versus running without prior activity.

Recent research has highlighted that running performance during a triathlon is enhanced by those triathletes that can maintain a longer SL during the final stages of a race (20). That is, those with a longer stride run faster and have a better overall performance. It may be that those who maintain a longer SL are more fatigue resistant or have physical characteristics that enhance SL.

Previous triathlon and running research has shown that the physical characteristics of athletes may play a role in determining performance. The participant's anthropometry was found to account for 47% of the variance in triathlon performance (22) where low levels of adiposity and proportionally longer limb lengths positively influenced swimming and running performance during triathlon (2). Investigations into body size and running mechanics have revealed that SL is related to lower limb length (LLL) and stature in sprinters (17) and distance runners (33) and that a relationship may exists between SR and whole body mass (35). It is also well established that endurance runners have low levels of body mass which relates to improved running performance (18, 31, 36). Highlighting that, it may not be only physiological characteristics determining success, but a combination of other characteristics such as anthropometric variables.

Preceding studies have highlighted that running SL during a triathlon event is significantly associated with running ability and final finishing position (20). It has been suggested that a relationships exists between an athletes' body size and self-selected SR and SL in runners (6), however, running mechanics and performance in triathlon can be affected by the prior swimming and cycling disciplines (16). As final race outcome is highly related to running ability after cycling, there is a need for greater information regarding running, during triathlon competition, to assist triathletes and coaches to improve performance and talent identification. Hence, this study sought to determine whether the body mass and heights of senior elite male triathletes correlated with the SR and SL used during competition. It is hypothesized that if such a relationship exists, that taller triathletes would utilize a longer SL and lower SR and, heavier triathletes would employ a lower SR during the run at the end of triathlon competition.

METHODS

Participants

Subjects were comprised of 37 male senior elite triathletes (mean age = 27.2 $\pm$ 3.0 y) from a world championship event. The sample included only those subjects who completed the event and where data were available for both running mechanics and body size. Ethics approval for this study was obtained from the Human Rights Committee of the University of Western Australia, and all participants signed a consent form after being informed of the study requirements.

Protocol

Prior to competition, mass and height were measured following established procedures (5). Triathletes were then videotaped at 25 Hz (Panasonic AG-450, Japan) during competition and individually selected SR and SL was determined by digitising the video via Video Expert II Coach (Australia, 1999) computer software. The event consisted of a 1500 m, one lap, wetsuit swim (18.8°C); a six lap, 40 km draft legal cycle, and a 10 km run conducted over a flat, three and a half lap course.

Table 1. Data collection points during the run

Run Lap	Distance (km)
Post T2	1.20
1	3.00
2	5.45
3	7.90
Pre-finish	8.50

Note: Post-T2 = first run data collection point after the second transition. Pre-finish = final run data collection point prior to finishing the event

On the run course, a camera was placed 1200 m after the cycle-to-run transition and 30 m perpendicular to the run course allowing collection of data as soon as the triathletes entered the looped part of the run course (Post-T2), during each lap and then 1.5 km from the finish (Pre-finish) (Table 1). The road surface was marked at 1 m intervals with reflective masking tape for calibration when digitising.

Statistical Analysis

The video was replayed after the event and SRs and SLs for each triathlete were calculated at each of the points described above from the run. A stride was defined as completing a complete running cycle from toe-off of one foot to the subsequent toe-off on that same foot. The SL was determined as the horizontal distance covered with each stride (m) and the SR defined as the number of strides completed each minute (strides.min^{-1}). Two complete strides were measured at each point and the means were recorded.

Each data point during the run was coded either SR for stride rate or SL for stride length. Data were entered onto an SPSS spreadsheet where the mean and standard deviation for each collection point were determined. Pearson correlations were then undertaken to determine the extent of the association between SR and SL, and body mass and height. Also a correlation between height and mass was conducted to determine the strength of the relationship between these two variables.

To account for variations in height the SL used by each triathlete was converted to a percentage of their height. To further determine the relationships between body size, run mechanics, and performance, the fastest third (n=12) triathletes were compared with the slowest third (n=12) via a one way ANOVA to determine any significant differences. In this study, from the participants that were measured, the fastest 12 runners were also the highest placed finishers and the slowest 12 runners were also the lowest placed finishers. The alpha level was set at p<0.01 for all statistical analysis.

RESULTS

Elite male triathletes reported a mean body mass of 69.4 kg (±5.4), height of 179.7 cm (±6.2) and BMI 21.5 kg/m² (±1.04). A mean run time for the 37 triathletes of 32 min 38 s (±1:24) was recorded for the final 10 km run with a range of 31:02 to 38:07. A strong and positive correlation existed between height and mass (r= 0.794, p<0.0001). Run time did not correlate significantly with height (r=-0.402, p=0.013) or body mass (r=0.149, p=0.378).

Table 2. The mean (±sd) stride length (SL) and stride rate (SR) data & correlations with mass and height, for male senior elite triathletes (n=37).

	mean	sd	mass correlation	height correlation
SL	(m)		(r)	(r)
Post T2	3.0	0.20	0.12	0.17
SL1	3.4	0.18	0.19	0.48*
SL2	3.3	0.18	0.38	0.42*
SL3	3.2	0.21	0.33	0.48*
SR4	3.1	0.22	0.25	0.44*
Mean SL	3.2	0.16	0.30	0.47*
SR	(stides.min^{-1})			
Post T2	92.1	3.1	-0.48*	-0.38
SR1	91.3	3.7	-0.46*	-0.55*
SR2	91.3	3.6	-0.33	-0.21
SR3	90.2	3.6	-0.07	0.00
SR 4	91.0	3.1	-0.05	0.09
Mean SR	91.2	2.4	-0.40	-0.30

Note: * = significant correlation (p<0.01)

Over the course of the final 10 km run, triathletes recorded a mean SR of 91.2 (±2.4) rpm and mean SL of 3.2 (±0.16) m which yielded a significant (p=0.002), but negative correlation (r=-0.49). This mean SL was 178% (±8%) of the triathletes' height. Self-selected SR and SL measures for each data collection point, and their subsequent correlations with body mass and height, are presented in Table 2. Triathletes recorded significant and positive correlations between SL and height. The relationship between mean SR and mass approached significance (r=-0.40, p=0.014). No relationship was noted between SL and body mass.

When comparing the fastest third and the slowest third of this sample it was revealed that the faster triathletes used a significantly longer SL and the SL, as a percentage of height was greater (Table 3).

Table 3. The mean (±sd) stride length (SL), stride rate (SR), mass, height, and SL as a percentage of height (SL percent) for fastest third and slowest third of triathletes (n=37).

	Fastest 1/3 (n=12)	Slowest 1/3 (n=12)	p
Mean SR	91.2 +1.8	90.6 +2.5	0.459
Mean SL	3.3 +0.1	3.1 +0.2*	0.0001
Height	181.4 +5.6	176.8 +7.1	0.046
Mass	68.2 +4.8	69.2 +6.9	0.686
SL percent	1.84 +0.70	1.74 +0.09*	0.006

Note: * = significant difference between groups (p<0.01)

DISCUSSION

Previous research has shown a relationship between running SL and running performance during triathlon competition for elite males (20). This study sought to determine if body size (height and mass) influence SL selection and thus if it may be useful in identifying potential success in triathlon competition.

It is evident in the current study that there are strong relationships between the SL used throughout the run and height of the triathletes, thus supporting the hypothesis that tall triathletes utilise a longer SL. Body mass did not relate to SL or SR. The results also indicated that the faster runners used a longer SL during competition. However, when comparing the heights and masses of the fastest runners with the slowest runners in the sample no significant difference was recorded, although height did approach significance ($p=0.046$).

Anthropometry

The stature (179.7 $\pm$ 6.2 cm) and body mass (69.4 $\pm$ 5.4 kg) of the senior elite male triathletes of this study were similar to senior elite male competitors in the 1997 Triathlon World Championships (180.1 $\pm$ 5.9 cm and 72.6 $\pm$ 6.0 kg, n=19) (1). Although not a significant change in mass ($t(54)=1.95$, $p<0.05$), this current data appears to indicate a declining trend. As 1997 was the first year when drafting was permitted in competition, it may be triathlete body shapes are continuing to evolve over time as the sport of triathlon develops beyond its infant stages as has been shown in other sports (32).

Body fat contributes a small proportion of total mass in triathletes (23) and those with lower levels of adiposity tend to perform better (2, 22). Thus, a change in skinfold measures could indicate a significant reduction in fat mass, but may not divulge a significant change in total body mass. Therefore, it may be possible that, if other anthropometric variables were measured and compared with the 1997 triathletes, changes may be apparent. The results indicate a need to follow up these initial anthropometric data in order to compare the current body shapes and compositions of elite triathletes with their predecessors.

SL & Height

It is clear from this study that there is a relationship between the height of the elite triathletes and their selected SL. That is, taller triathletes were able to take longer strides. This is a significant finding, as previous research has shown that the SL used during the run is an important predictor of run time and triathlon performance, where the better performers were those who maintained a longer and more consistent SL (20). Other researchers have highlighted a relationship between SL with height and LLL when sprinting (10 m/s) (17). The triathletes in the present study ran at approximately 5m/s. In contrast Cavanagh and Williams (6) revealed that SL and LLL were not significantly related while running at a moderate speed of 3.83 m/s. Thus, such relationships between SL and body size may be dependent on running speed.

SR & Mass

It has been suggested a relationship between SR and body mass exists (35). However, the lack of a significant relationship in the current study does not support this finding and as such does not support our original hypothesis of heavier triathletes using a lower SR. This correlation between SR and body mass approached significance ($p=0.014$) and it may be possible that if these triathletes' run mechanics were measured when in an unfatigued state, that is with no prior swimming and cycling, the outcome may be different. However, this data was not collected during the present study, and as such may be an area for future investigation.

This non-significant result may also be explained by earlier research presenting theories suggesting if body shape is similar, the absolute body size may not have a great influence on the rates of muscular contraction (8, 39). Wilkie (39) suggested maximal velocity of contraction remains relatively constant across all subjects despite varying maximal force production in geometrical similar animals. The results of the current study indicate a strong relationship between increasing mass with increasing height (r=0.794) suggesting possible geometric similarities between the tall and short triathletes.

Proportionality
This suggestion of geometric similarity leads to the question of proportionality rather than absolute values relating to performance. A prior study suggested that the proportionality of triathletes contributes to a larger role in performance than absolute size (2). Hence, the link between body size and shape with selected SL and, thus, performance becomes clearer. That is, it is more likely that the longer strides result from taller athletes.

The proportional limb lengths of triathletes were better predictors of triathlon performance than absolute size (22) where proportional thigh length of male triathletes significantly correlated with run time (r=-0.314, p<0.05) (2). That is, those with longer levers, in the form of legs and arms, appeared to have a mechanical advantage as they performed better during the event. Although the results of the present study provide a significant correlation between height and SL, it could be that LLL or the relative LLL is a better predictor of SL. This is because some of the shorter triathletes might have absolute or relatively longer legs than the taller competitors. As LLL was not measured in the current study, further investigation is required to clarify this assumption.

No differences in body mass or height of fast and slow triathletes were recorded, although height approached significance (p=0.46). However, the important finding here is that the faster triathletes took proportionally longer strides as indicated by a significantly larger SL as a percentage of height.

Body Size and Performance
Landers et al. (20) noted only a small variation in SRs used throughout triathlon competition. The lack of significant differences between SRs used by athletes of differing ability might suggest that the weak, negative correlation between SR and body size is the result of the triathletes selecting the most efficient SR/SL combinations. This is supported by the negative association between body size and SR, and the positive correlation with SL. That is, those who are taller and heavier, use longer strides and slower cadences.

In view of the fact that all the subjects were elite competitors in a world championship event, it could be that the homogeneity of the group masked the influence of body size and shape. If an ideal kinanthropometric model exists, these athletes should be closest to such a representative cluster. Hence, further analysis of these parameters from a larger sample with a wider range of abilities could help to clarify the matter. Similar results have been obtained from elite swimmers, where anthropometric variables accounted for a greater variation in stroke length (89%) than stroke rate (41%) (13).

Prior studies suggest that with increasing running speed there is an increase in SL initially, followed by an increase in SR (10, 40). Taylor (35) also noted that bipedal and quadrupedal animals maintained the same frequency across a two to three fold increase in speed. Meaning, there is no change in SR but change in SL to accommodate the variation in speed.

A limitation of this study to note is that no SR or SL data were collected from the participants in an unfatigued, controlled environment. Previous research has indicated that prior activity such as swimming, cycling or running prior to completing a 10 km run increases fatigue which can alter running mechanics (4, 12, 16, 20). That is, there is a possibility that the participants may choose different SR/SL characteristics while running at a similar speed without prior cycling and or swimming which may have a stronger relationship to the triathletes' body mass or height. This present study sort to determine whether the body mass and heights correlated with the SR and SL selected within competition, as such SR and SL were not measured in this study in an unfatigued state one can only speculate on the possible outcomes. This obviously leads to the possibility of further investigation.

Summary

This study sought to link together the physical structure of triathletes with running mechanics and performance. The SRs and SLs were measured during competition, and body mass and height measured prior to competition. Senior elite triathletes competing in the 2000 TWC were investigated and a correlation matrix developed to determine the relationships between the variables. The SLs were positively related to height ($p < 0.01$). That is, the taller triathletes used longer strides. It could be argued that the athletes self-selected themselves into the sport of triathlon based on optimal body height and mass measures. Further research is warranted to examine the effects of cycling on the subsequent run discipline during triathlon and if body size and shape of triathletes have evolved as the young sport of triathlon develops.

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