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Self-Selected Pacing Strategy and Lactate Response in Individual Medley Time Trials

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Title: Self-Selected Pacing Strategy and Lactate Response in Individual Medley Time Trials

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ABSTRACT

The 200 and 400-yard individual medley (IM; 200 IM and 400 IM, respectively) are two swimming events that challenge swimmers' versatility. Each of these events has different physiological requirements, where the 200 IM is viewed as an anaerobic event and the 400 IM as an aerobic event. Additionally, the IMs require performance in all four competitive stroke disciplines in a specific order (butterfly, backstroke, breaststroke, and freestyle), with each stroke requiring a different magnitude of intensity, efficiency, and speed. Purpose: To study the different pacing strategies and corresponding blood lactate response during the 200 IM and 400 IM in National Collegiate Athletic Association (NCAA) Division III swimmers. Methods: 10 NCAA Division III swimmers (age: 19.7 ± 0.95yrs, height: 169.0 ± 6.4cm, weight: 71.8 ± 0.95kg) performed a simulated time trials of the 200 IM and 400 IM during the competitive season. Blood lactate (BLA) was measured prior to warm up, prior to racing, and at the completion of the time trial. Change in blood lactate (ΔBLA) was calculated from the pre and post BLA. Splits were taken for each lap (50 yard) of each stroke, and segment (50,100 yard) velocities were calculated. Additionally, percents of the total time each stroke took were also calculated. Multiple repeated measures ANOVAs were used to determine significant differences. Results: No significant differences ($p>0.05$) were reported between the BLA Post 200 IM (8.9±3.2 mmol/L) and BLA Post 400 IM (8.87±2.4 mmol/L), nor in ΔBLA_{2IM} (7.56±3.25 mmol/L) and ΔBLA_{4IM} (6.11±2.82 mmol/L). Rate of perceived exertion (RPE) was found to be significantly ($p<0.01$) greater following the 400 IM (9.1±0.88) versus the 200 IM (7.4±0.84). Significant interactions were found ($p<0.05$) between the stroke velocities and stroke percentage of total time for the 200 IM and 400 IM. Conclusion: Measurement of BLA showed that there was an equivalent amount of anaerobic involvement between the 200 IM and 400 IM but the pacing strategies were different.

KEY WORDS: Time to completion, Division III, Blood lactate, 200 IM, 400 IM

INTRODUCTION

Collegiate swimming events range in distance from 50 yards (yds) to 1650 yds and consist of four different stroke disciplines; butterfly (FLY), backstroke (BK), breaststroke (BR), and front crawl, also known as freestyle (FR). Different combinations of strokes and distance races have different varying levels of intensity and efficiency. Sprints (200 yds distances and under) are shorter duration and higher intensity compared to distances (400 yds or longer), where the intensity is moderate for a longer duration. The stroke that is most efficient is FR, which is similar to BK (3). However, the least economical strokes that require the most amount of energy are FLY and BR (6). Researchers have shown that swimming 400 m uses less energy expenditure than 100 m and 200 m due to elongation of stroke distance and reduced stroke rate per length (2).

Swimming consists of anaerobic and aerobic events. The anaerobic events consist of 200 yds and less while the aerobic events comprised of 400 yds and above. The individual medley (IM) consists of two different distances, 200 yds, and 400 yds, with the 200 IM involving 50 yds of each stroke and the 400 IM involving 100 yds of each stroke. The Division III NCAA championship B cut time for 200 IM for females and males respectively is 2:06.23 and 1:50.93 (NCAA). The B cut time for the 400 IM respectively is 4:29.76 and 4:01.49 (NCAA). As a result of these duration differences, each distance of the IM may use different metabolic pathways. According to researchers, the 100m FR uses 66.8 % anaerobic energy,the 200m FR uses 65% of the aerobic system and 35% anaerobic, and the 400m FR uses 80% aerobic and 20% anaerobic energy (11). Therefore, it could be assumed the IM would follow similar energy systems as the freestyle races.

Since the IM utilizes all stroke disciplines in a particular order there may be an impact on the overall physiological demands due to differing pacing, stroke efficiencies, and stroke rates. FR is the fastest, most efficient, and the most commonly practiced, whereas FLY is stereotyped as being the hardest due to the bilateral, short axis stroke pattern requiring significant upper body strength and efficient upper body and lower body patterning to be successful. FR has been studied the most because it is the fastest stroke and most economical (2). The velocities were obtained from male finalists in the 2019 European Short-Course Swimming Championships, in order to fastest to slowest swimming velocity for males the 200 IM strokes, FLY 1.81 ± 0.04 m/s, FR 1.73 m/s, BK 1.63 ± 0.05 m/s, BR 1.38 ± 0.02 m/s, and for 400 IM swimming velocities in order from fastest to slowest, FR 1.66 m/s, FLY 1.63 ± 0.02, BK 1.47 ± 0.06, BR 1.34 ± 0.04 m/s (7). For females, the velocities for 200 IM were, FLY 1.62±0.03 m/s, FR 1.57 ± 0.03 m/s, BK 1.45 ± 0.04 m/s, BR 1.25 ± 0.02 m/s, and for 400 IM FLY 1.51 ± 0.02 m/s, FR 1.52 ± 0.04 m/s, BK 1.35 ± 0.06, and BR 1.19 ± 0.03 m/s (7). The 400 IM velocity for FR and FLY are fairly close together for both males and females. In National level Masters swimmers they were found to have increased final end spurt in the 200 and 400 m IM and FR was the fastest stroke velocity (9).

Different strokes will elicit different intensities due to differences in their velocities. A study was conducted that looked at the relationship between the time to reach Time Limit - minimum velocity- maximal oxygen consumption (TLim-vVO_2 max) and the minimum velocity that elicits maximal oxygen consumption (vVO_2 max) (2). The research found the relationship was inversely related, meaning that the faster the velocity, the faster a swimmer will reach maximal oxygen consumption (2). Fatigue onset will occur when swimming velocity is the fastest resulting in pacing strategies that differ for different distance and stroke events. This is similar to the concept of blood lactate (BLA). BLA is a measure of anaerobic involvement. The waste product of producing energy without oxygen is BLA. Swimming has a lower metabolic acidosis than other sports (2). One study analyzed the 200 and 400 m free and concluded that exercise intensity was correlated with maximal lactate steady state (8). As the velocity increased so did the blood lactate concentration (8). Speed along with technique is crucial in a race in order to diminish any possible drag and wasted energy.

Stroke rate (SR), stroke mechanics, and distance per stroke (DPS) can determine the differences in stroke intensity and efficiency. SR is how fast the arms are completing one cycle. DPS is how many strokes are taken each lap. The 200 IM has a faster SR than the 400 IM in all four strokes (2). A study was conducted using indirect calorimetry on male swimmers, which found the strokes in order from least to most energy expenditure were freestyle, backstroke, butterfly, and breaststroke (6). Faster swimmers have better technique due to efficiency and waste less energy per stroke (2). BR has the lowest velocity of all the strokes due to being the least efficient compared to other strokes (3). BR is a short axis stroke and predominantly reliant on the kick to propel the swimmer forward. The slower the stroke is the more energy consuming swimming becomes (10). Sprint swimming relies on energy in muscle stores, such as creatine phosphate, 45 seconds to 15 minutes is classified as middle-distance swimming, and the shorter anaerobic energy, phosphate and anaerobic glycolysis are used, however the amount of energy expenditure for each stroke is largely dependent on the individual (6). Another researcher found similar results. They studied the energy cost for each stroke, which resulted in the same order (5). The cost of each stroke was measured by using the variable of hydrodynamic resistance per propelling efficiency and overall efficiency (5). As swimming velocity increases, water resistance increases, resulting in an increase in energy expenditure (5).

The result of a race depends on each swimmer and how they strategize to pace the race, stroke skill, and other features. Negative pacing strategies are when the first half of the race is faster than the second because of the block start whereas positive pacing strategies are when the second half is of equivalent or faster speed to the first half. All-out pacing is just what it sounds like, all-out for the entire duration of the race. A study looked at national level swimmers and concluded that the 200 and 400 IM used negative pacing strategies (**3**). Another aspect that was analyzed looking at splits was comparing it to the swimmers best 100 FLY time, the results showed their 200 IM was 1 sec off the first 50 and their 400 IM split was 2.5-3 sec off (3). Another study analyzed a different group, namely masters swimmers. FR was the fastest stroke, followed by FLy, BK, and BR (9). This could have been due to a final spurt at the end of both IM distances. Elite swimmers use an all out pacing strategy compared to master swimmers (9). Masters use experience to start slow and finish fast.

Swimming consists of a variety of distances and strokes. The 200 IM and 400 IM differ in intensity because of the technique and velocity the different strokes and events require. The faster the swimming velocity, the more energy the swim will cost (2). The quality of the technique can impact a race positively or negatively. Most measurements of swimming have compared time, VO2 max, SR, DPS, and other components. A component that has not been compared to these is blood lactate. During competitive races, it is difficult to take measurements of BLA and the majority of research has been completed analyzing previous races. With the addition of BLA, the anaerobic involvement will be able to be measured with more precision because energy cost differs from swimmer to swimmer due to each individual being better at a certain distance, stroke, technique, and body shape. The purpose of this study is to analyze the different pacing strategies and BLA during two different distances of the IM.

METHODS

Experimental design

A quasi-experimental, repeated measure design was conducted to examine the pacing strategies and BLA differences between the 200 IM and 400 IM NCAA Division III male and female swimmers. Subjects first swam the 200 IM in one session and 400 IM in another. Each swimmer completed both events to their best maximal effort for time. Rate of perceived exertion (RPE) and blood lactate (BLA) were measured pre and post event, and with stroke splits were recorded.

Participants

Ten swimmers participated in this study (female: n=8, males: n=2, age: 19.7 ± 0.95yrs , height: 169.0 ± 6.4cm , weight: 71.8 ± 0.95kg). The subjects were recruited by word of mouth and email.

The inclusion criteria for this study included NCAA DIII Swimmers, ages 18-24, and a maximum of 5 years of collegiate swimming experience and the athlete had to be cleared by the athletic training staff to be able to fully participate with no restrictions. The exclusion criteria includes an athlete cannot participate in practice and/or maximal effort, and if an athlete receives disciplinary actions from the NCAA including supplement or drug violation, academic and ethical misconduct, etc., they will be excluded. An informed consent was provided and signed by each swimmer. This study was approved by the IRB #LHS2223028.

Protocol

After subjects were recruited they were assessed for body height (cm), weight (kg), age (years), and specialty stroke. Subsequent testing sessions consisted of the swimming portion at a local competitive 25 yard swimming pool.

Subjects completed a 1200 yd warm up (Table 1). During the first sessions swimmers swam the 200 IM and the second session swam the 400 IM.

Table 1: Warm up	
Type	Time
400 yd freestyle	On own pace
300 yd IM (kick, drill, swim by 25)	On own pace
2 x 100’s freestyle	1:30
100 IM	On own pace
8 x 25’s variable sprint (easy/fast, fast/easy, all easy, all fast)	0:30 seconds

Before each subject began warming up, BLA (Lactate Plus, Nova Biomedical; Waltham, MA) were measured. After warming up, BLA was measured again.

Time trials were timed until completion with lap (50 yard) splits attained via stopwatch (Ultrack, Model 495, Gardena, CA). Time started when the researcher exclaimed “GO” and stopped upon a hand touch on the wall at the conclusion of the event. Splits were taken at the end of each lap with a hand or foot touch as rules allowed. The same administrators took splits during each race to ensure reliability and validity. After each event, the subjects RPE was recorded using an Borg 0 to 10 RPE scale, with 0 being rest and 10 being maximal effort. The subjects were familiarized with the RPE scale before completion of any swimming events. After each event, BLA was measured again. These steps were repeated for each event. Encouragement was provided during the events by other subjects and administrators to stimulate maximum effort similar to competition.

Statistical Analysis

Descriptive statistics (mean and SD) were used to characterize the subject's demographics (Table 2). Multiple repeated measures analysis of variances (ANOVAs) were completed comparing 200 IM and 400 IM stroke splits, velocities (m/s), and split percent of total time (%total) with Bonferroni adjustments used for post hoc analysis of significant effects. Four paired-sample T-tests were used to assess 200 IM and 400 IM differences in pre BLA, post BLA, ΔBLA and RPE. Pearson r correlation was used to determine the relationship between BLA results (post BLA and ΔBLA) and event velocities. All statistical procedures were performed using JASP 17.1 (Amsterdam, Netherlands . Statistical significance level will be set *a priori* at 0.05.

RESULTS

Table 2, shows the event vs stroke split velocities were not significant (p >0.05) for BK, BR, FR, but 200 IM FLY velocity (1.48±0.11m/s) was significantly (p<0.001) greater than 400 IM FLY velocity (1.26±0.16m/sec).

Table 2: Mean (SD), Velocities (m/s)		
	200 IM (m/s)	400 IM (m/s)
FLY	1.48±0.11	1.26±0.16
BK	1.18±0.14	1.09±0.12
BR	1.02±0.08	0.98±0.06
FR	1.26±0.05	1.21±0.08

A paired-samples t- test reported no significant difference (t(9)=0.13, p = 0.89) comparing the mean scores of BLA Post 200 IM and BLA Post 400 IM (Table 3). The mean of BLA Post 200 IM (8.9±3.2 mmol/L) was not significantly different than BLA Post 400 IM (8.87±2.4 mmol/L). Similarly, there was no significant difference (t(9)=1.43, p=0.19) comparing ΔBLA200 IM (7.56±3.25 mmol/L) and ΔBLA400 IM (6.11±2.82 mmol/L). A paired-samples t test, reported a significant difference (t(df)=(-5.7(9)), p < 0.01) comparing the mean scores of RPE 200 IM and RPE 400 IM. The mean of RPE 200 IM (7.4±0.84) was significantly lower than RPE 400 IM (9.1±0.88)(Table 3).

Table 3: Paired Sample t-Tests of Pre, Post and Change in Blood Lactate along with Rate of Perceived Exertion			
	200 IM	400 IM	P - value
Pre BLA (mmol/L)	1.95±0.89	2.76±1.23	0.14
Post BLA (mmol/L)	8.9±3.2	8.87±2.4	0.89
ΔBLA (mmol/L)	7.56±3.25	6.11±2.82	0.19
RPE (0-10)	7.4±0.84	9.1±0.88	<0.01*

Table 4 presents Pearson's correlation table corresponding to the relationships of post BLA ΔBLA and race velocities. A significant post IM BLA ($r=0.99$; $p<0.05$) relationship was found with ΔBLA levels for each event (200 IM and 400 IM).

Table 4: Pearson's correlation (r) for variables (ΔBLA_{2IM}) significantly correlated with performance ($\Delta BLA_{400\ IM}$) (p , 0.01).

	200 IM Velocity (m/s)	400 IM Velocity (m/s)	Post BLA 200 IM (mmol/L)	Post BLA 400 IM (mmol/L)	$\Delta BLA_{200\ IM}$ (mmol/L)	$\Delta BLA_{400\ IM}$ (mmol/L)
200 IM Velocity (m/s)						
400 IM Velocity (m/s)	r = 0.58 p = 0.08					
Post BLA 200 IM (mmol/L)	r = .31 p = .39	r = 0.16 p = 0.65				
Post BLA 400 IM (mmol/L)	r = .08 p = .83	r = 0.17 p = 0.63	r = 0.51 p = 0.12			
$\Delta BLA_{200\ IM}$ (mmol/L)	r = .25 p = .48	r = 0.13 p = 0.72	r = .99 p < 0.001*	r = .61 p = .05		
$\Delta BLA_{400\ IM}$ (mmol/L)	r = -.08 p = .83	r = -0.043 p = 0.91	r = .32 p = .38	r = .90 p < 0.001*	r = .45 p = .20	

A repeated measures ANOVA reported a significant interaction ($F(1,3) = 4.28$, $p < 0.05$) between IM (200 IM and 400 IM) stroke (FLY, BK, BR, FR) velocities. A pairwise comparison revealed that there were significant differences between the 200 IM FLY (1.48 ± 0.11 m/s) and 400 IM FLY (1.26 ± 0.16 m/s). There were no significant pairwise differences ($p > 0.05$) between the 200 IM and 400 IM for the other strokes (BK, BR, FR) (Fig. 1).

A repeated measures ANOVA reported no significant interaction ($F(1,3) = 2.02$, $p > 0.05$) between IM (200 IM and 400 IM) and stroke (FLY, BK, BR, FR) percent time (Fig 2).

There was an expected, following one-way ANOVAs significant differences in strokes (FLY, BK, BR, FR) splits for the 200 IM ($F(3,27) = 77.10$, $p < 0.05$) and 400 IM ($F(3,27) = 12.93$, $p < 0.05$). For the 200 IM, the FLY(31.12 ± 2.9s) was significantly ($p<0.05$) faster than the BK (39.24 ±4.24s), BR(44.92 ± 3.53s), and FR(36.32 ± 1.36s). The BK was significantly faster than the BR but significantly slower than the FR and the BR was significantly slower than the FR(36.32 ± 1.36s) (Fig 3). For the 400 IM, the FLY (73.90 ± 12.22s) was significantly ($p<0.05$) faster than the BR (94.07 ± 6.06s) as was the FR (75.88 ± 5.26s) compare to the BR (94.07 ± 6.06s) (Fig 4).

Figure 1: Event velocities for each stroke between 200 IM and 400 IM of men and women. Data expressed as means and SDs.

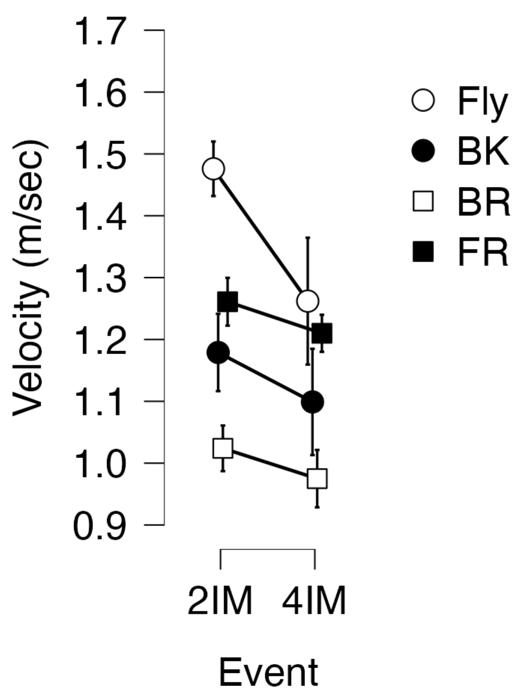


Figure 2: Percent of Total time for each stroke between 200 IM and 400 IM for men and women. Data expressed as means and SDs.

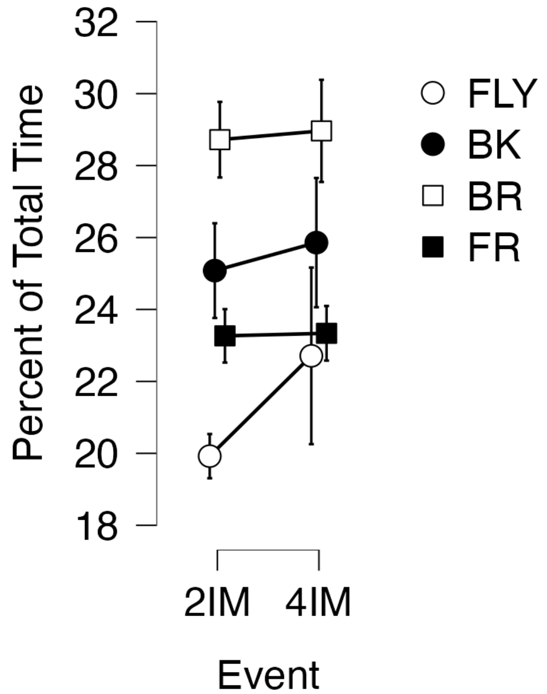


Figure 3: Average 200 IM velocities for each split of stroke throughout the duration of the event.

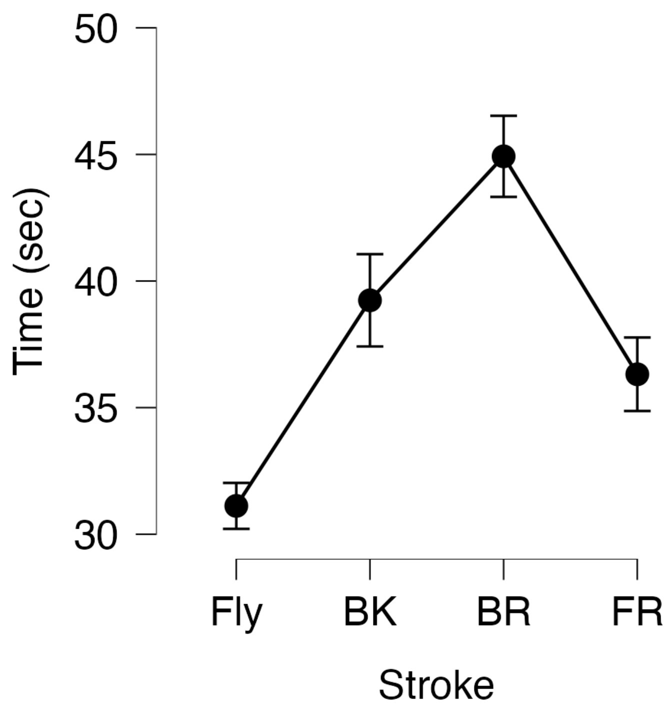
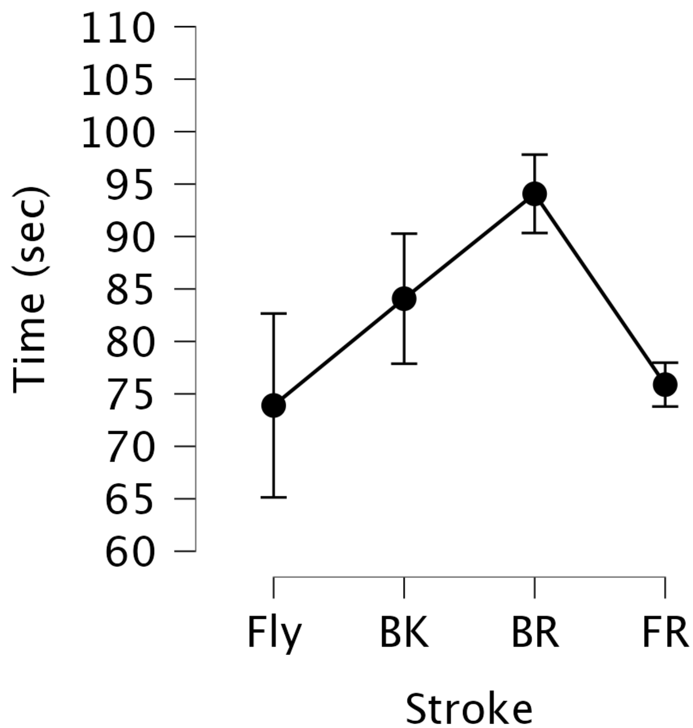


Figure 4: Average 400 IM velocities for each split segment of stroke



DISCUSSION

This research was interested in describing the metabolic and performance differences between two different swimming events of two different lengths (200 IM and 400 IM) in NCAA Division III swimmers. As mentioned previously, the IM, is a competition event that combines all four stroke disciplines (FLY, BK, BR, and FR, respectively) performed at the 200 and 400 yard distances is a unique event in that it challenges the athlete both metabolic and through technique. As such, it was hypothesized that the metabolic demand, as assessed by blood lactate (BLA), would be greater during the shorter, more intense 200 IM when compared to the longer 400 IM. However, our results did not support that hypothesis, as both the 200 IM (BLA 8.9±3.2 mmol/L) and 400 IM (8.9±2.4 mmol/L) peak immediate post lacates were not statistically different. This was not expected due to the time frame of the events. Simply by nature of the two events, the 400 IM takes double the amount of time than the 200 IM, 156.5±8.9 seconds vs. 325±19.2 seconds, respectively.

Pre-BLA, post-BLA, and ΔBLA values between the two different distances were not significantly different (p>005). BLA is a biomarker of glycolytic metabolism and an indicator of anaerobic performance. The results concluded that the same amount of fatigue occurred at the conclusion of 200 IM and 400 IM. Previous research contradicts the results, that the highest BLA was seen following 100 and 200 m events versus the 50 and 1500 m events, this was expected due to the higher glycolytic energy requirement contributions between the two different IM races (1). The short duration of 50 m is able to rely on the stored energy of adenosine triphosphate - creatine phosphate (ATP-PC) resulting in less BLA compared to the events of lengths up to 400 m (1). More contradictory research showed that in competition, the event that had the highest BLA concentration was 200 yd IM, the reasoning behind this was because of the greater demand of muscle recruitment during the combination of all four strokes (12). The BLA values for the 200 IM were 28.1 mM/L and 24.5 mM/L, these values are higher due to being during competition and the athletes having swam multiple events (12). Compared to our time trial values of 8.9±3.2 mmol/L for 200 IM. A supporting explanation for the same BLA results is that BLA for IM events has been found to be higher than when compared to other strokes (1). The 200 IM relied on stored energy at the beginning of the race, then switched to glycolytic. Phosphocreatine (PCR) quickly runs out and switches to fast glycolysis. 400 IM is a longer duration and could use fast glycolysis too. Resulting in the same end product for both races, lactate.

Each stroke in the IM has a different speed for each swimmer which can result in a different energy expenditure. FR is known as the most efficient stroke (3). FR velocity in the IM showed the second fastest speed in the 200 IM and 400 IM which was followed closely by FLY. FLY and BR energy expenditure is two times higher than FR and BK (6). At slower speeds FLY can become the least economical stroke (3). This is because of the stroke mechanics and increased amount of drag. However, it was evident that this was the fastest portion of the swim in both the 200 IM and 400 IM. Evidence that supports that FLY requires the most energy expenditure is that the BLA values found in FLY were the highest (1). BR on both distances was the slowest swim velocity. This was also found in National level swimmers, where the most velocity lost throughout a race is BR (7). Supporting evidence to enforce that BR is the least economical stroke found that BLA was the lowest for BR compared to the other strokes (1). Therefore, from a coaching perspective to improve a race, BR is the area where the most improvement in the IM can occur.

We were also interested in describing the performance (pacing) between the two events. The only significant difference in pacing was found to be in FLY between the 200 IM and 400 IM. The rest of the strokes were more evenly paced between the distances. The results concluded that the Division III swimmers used a positive or all out pacing strategy for the 200 IM and a negative pacing strategy for the 400 IM. For both the 200 IM and 400 IM, FLY velocity was the fastest followed by FR, BK, and BR. This was the same found in International swimming competitions (3). FLY was the fastest stroke for both 200 IM and 400 IM (3). Division III swimmers do not compete to as high of levels as the swimmers in the International competition study do. Taking that into account, the same pattern of velocity was found in Division III swimmers, but with slower overall velocities. The velocities of the 2019 European Short-Course Swimming Championships were closer together with less deviation for all four strokes (7). The 400 IM swimmers in the European Championships found the similar velocities in FLY and FR as our current study. The 400 IM FLY velocity was 1.51±0.02 m/s and 400 IM FR velocity was 1.52±0.04 m/s (7). Compared to our 400 IM velocities of FLY 1.26±0.16 m/s and FR 1.21±0.08 m/s. Similar pacing is found between Division III and national level swimmers. This strategy for swimming the IM has been found to be used in two different levels of competition, therefore there is a general consensus to how the IM is paced. Coaches can use this corresponding data to teach their athletes how to pace a 200 IM and 400 IM.

The 400 IM FLY and BK at the start of the event were faster than the BR and FR at the end of the event. This would indicate that the longer the distance the value of equal pacing increases performance. Some factors that can come into play are mechanics of the stroke, stroke rate, stroke length, and faster turns. The 200 IM benefits from the block start because of initial velocity. That is the fastest speed a swimmer will reach during the race. Start time only affects races that are 200 and shorter (7). The 400 IM has the same initial velocity but the duration of each stroke segment is longer. Movement patterns are simpler for the 200 IM. Swimmers are able to go all out for the whole duration of the race. Little thought was put into strategy other than making sure to go as fast as possible. During the 400 IM swimmers have to regulate their rate in order to not over exert themselves at the beginning of the race. Depending on the swimmer's specialty strokes will decide if they will go out slower in order to ensure enough energy is left to finish the race off strong. Benefits for a swim coach, with longer distance training in the 400 IM it can lead to increased power which will maximize the rate of lactic acid production and improve the muscles ability to clear the lactic acid (6). This will allow the swimmer to see improvements in their performance.

An exploratory outcome that we investigated was the swimmer's perceived exertion during the two events. Our results demonstrated that the 400 IM was perceived to be significantly more difficult than the 200 IM (7.4±0.84 vs. 9.1±0.88). This supports the reasoning behind the different pacing strategies and BLA between events. The 200 IM is a sprint race compared to the 400 IM where a pacing strategy must be planned. The 400 IM is stereotyped as being one of the hardest races in swimming. That is due to the length and time of the event, and the complexity of being able to swim every stroke efficiently for a longer duration of time. Swimming 50 yds of each stroke is easier than swimming a 100 yds of each stroke. Most collegiate and national swimmers specialize in one or two strokes and sprint, mid-distance, or distance events. Therefore, one stroke is normally not as strong as the rest. That is where the longer the distance, the harder swimming certain strokes come into contention. Swimmers must be able to maximize their efficiency of every stroke in order to minimize fatigue and result in the fastest time possible.

The main conclusions pointed out that both distances of the IM had the same amount of anaerobic involvement due to the BLA values being similar. This was regardless of the RPE which the 400 IM was rated to be harder than the 200 IM. This can help coaches understand metabolic demand of races and take into account for analyzing and training their athletes. Division III swimmers pace similar to National level swimmers who compete at a higher competition level. The 200 IM is a simpler race because the only strategy is to start as fast as possible and hang on, compared to the 400 IM which has more overall thought into how to negatively pace.

A limitation of the study regarding blood lactate is that it was taken two minutes after each subject finished their event. Due to this time frame, peak blood lactate may not have been evaluated. The first session consisted of the 200 IM which was completed before taper and championship season. The second session was the 400 IM which was conducted postseason a week after championship season. Therefore, this was most of the subjects' first time entering the water and taper could have played a factor in their results. The original goal of the study was to look at the intensity via heart rate (HR) of each stroke within the two distances of the IM. Polar H10 chest strap monitors were used but were not able to receive HR once the swimmer was completely submerged underwater. Another issue with the monitors is when swimmers would dive in the water the chest strap would roll down to their stomach. Tape and other measures were used to avoid this, but nothing was efficient. The size of the study was a limitation due to not many subjects and being predominantly female.

It is important to encourage future research about studying the difference between NCAA divisions in pacing strategies and blood lactate response. Each division has a different level of competition that could elicit different responses. Another aspect that could be researched is the difference between tapered and untapered and following any changes during the duration of a season. Each of the strokes can be further researched, especially FR due to it ranging from 50 yds to 1650 yds.

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