

Pre-Race Deep-Breathing Improves 50 & 100-yard Swim Performance in Female NCAA Swimmers

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Abstract

The purpose of this study was to examine the effects of a 30sec or 2min deep-breathing exercise on a 50-yard and 100-yard freestyle performance. Methods: Seven competitive female NCAA (Division I and Division III) swimmers performed a 50-yard and 100-yard freestyle sprint either in normal conditions (DB_{NO}) after deep-breathing of 30sec (DB₃₀) or 2min (DB₂) of deep-breathing. Results: Average velocity for the 50-yard freestyle was not significantly faster after the DB₃₀ (DB_{NO} 1.76 ± 0.12 y/s vs. DB₃₀ 1.77 ± 0.10 y/s P = 0.37). Average velocity for the 100-yard freestyle was also not significantly faster for the DB₃₀ (DB_{NO} 1.63 ± 0.11 y/s vs. DB₃₀ 1.63 ± 0.13 y/s P = 0.62). However, faster swim times were observed in both the 50-yard freestyle (50 free: DB_{NO} 28.45 ± 1.90sec vs. DB₃₀ 28.18 ± 1.59sec, P > 0.23).and 100 freestyle (100 free: DB_{NO} 61.73 ± 4.33sec vs. DB₃₀ 61.54 ± 5.11sec P = 0.79) after DB₃₀. The DB₂ resulted in slower swim times for both 50 and 100-yard swims when compared to DB_{NO} (DB_{NO} 28.45 ± 1.90sec vs. DB₂ 28.85 ± 2.21sec P = 0.29; DB_{NO} 61.73 ± 4.33sec vs. DB₂ 62.15 ± 5.52sec P = 0.58, respectively). Conclusions: A pre-race, voluntary 30sec deep-breathing procedure resulted in slight improvement in time for the 50-yard and 100-yard freestyle race, which could potentially translate to a competitive advantage.

Introduction

The depth of competition in elite swimming continues to increase with time deficits between first and last place decreasing (Stanula et al., 2012). The separation between first and second, or eighth place, is differentiated by hundredths of a second. Athletes will continue to search for legal ways of enhancing performance in order to gain that edge over their competitors. Most ergogenic aids, usually nutritional in nature, are expensive and perhaps not available to everyone. However, voluntary deep-breathing before a sprint event could provide a free, effective performance enhancement.

High intensity exercise results in a marked decrease in blood and muscle pH. The body will attempt to maintain acid-base balance by utilizing intracellular and extracellular buffers. One voluntary and cost-free buffer is deep breathing. A bout of voluntary deep-breathing can lower individual baseline CO₂ levels in the blood prior to exercise delaying the time to fatigue (Whipp, 2007; Ozcelik et. al., 1999), and potentially give the athlete an ergogenic advantage.

When the pH of blood rises due to deep-breathing, phosphofructokinase (PFK), a rate limiting step in glycolysis, shows increased activity in muscle cells. A byproduct of glycolysis is lactate and has been shown to increase due to deep-breathing (White et. al., 1969). The alkalizing effect also slows activity of pyruvate dehydrogenase (PDH), an aerobic enzyme and rate limiting step in the Krebs cycle, which results in suppression of aerobic metabolism. The abatement of the aerobic energy system from deep-breathing results in an additional increase in anaerobic metabolism to compensate (Jones & Jurkowski, 1979; Ziegler, 2002; Chin, 2007, Fujii, 2015).

Considering the increase in anaerobic metabolism and decrease in aerobic metabolism associated with deep-breathing (DB), it is plausible that a DB procedure might improve sprint swim races where a majority of anaerobic metabolism occurs. The point of equal aerobic and anaerobic energy contribution in a swim race is estimated to be about :50 to :55 seconds (Rodríguez & Mader, 2011). Thus, the point at which aerobic metabolism approaches equal contribution to anaerobic metabolism (55sec) is where DB could have ill effects upon performance, i.e. 200yard/meter (y/m) races and longer. In swimming, the aerobic contribution to a sprint swim has been estimated to range from 2% (Houston, 1978) to 33% (Peyrebrune, 2014) and depending on the trained status of the swimmer, takes 40-90sec to reach maximal functioning (Rodríguez & Mader, 2011). Most 100y/m races are well under the time it takes for aerobic processes to reach full power. Therefore, DB could work for 100y/m races, for an elite male or female freestyler. Slower swimmers, who's times are greater than 55sec, and have a greater aerobic contribution to their race, would probably not benefit from any DB procedure and may possibly hinder performance as DB may suppress the aerobic system.

To date there has been few published studies investigating the performance benefits of deep-breathing prior to a swim performance. Jacobs et. al. (2015) put elite level swimmers through a 30sec deep-breathing protocol prior to a 50-meter swim and found improvements in time (sec) and fewer breathing cycles. Other studies have shown a positive correlation to performance enhancement when deep-breathing ranged from 30sec to 15min (Ward, 1983; Cummin, 1991; Jacob, 2008). To date no research has looked at deep-breathing prior to a 100-meter/yard event. Furthermore, no studies have explored an extended deep-breathing protocol of 2min in swimming. A 15min DB procedure is not practical as swimmers usually arrive behind the starting blocks a few minutes before their race. However, a 2min bout of DB could be performed prior to a 50-yard/meter or 100yard/meter swim to evaluate the positive results of previous DB studies utilizing a longer than 30sec protocol (Whipp, 2007; Ozcelik et. al., 1999).

The purpose of this study is to determine whether a 30sec or 2min deep-breathing protocol has performance benefits on a 50 and 100-yard freestyle swim. Furthermore, to determine if there is an improvement in stroke rate,

stroke count, stroke length, and number of breaths. Breathing has been shown to disrupt swimming technique resulting in slower swimming speeds (Psycharakis & McCabe, 2011). Lastly, to look at blood lactate levels after each swim to determine if these levels are significantly increased after deep-breathing.

Methods

Subjects

Seven female ($170.1 \pm 7.1\text{cm}$, $67.09 \pm 10.9\text{kg}$) Division I and Division III NCAA college swimmers volunteered to participate in this study. Subjects performed all testing in the post-season, after conference championships. All participants consented to the study and all procedures were approved by the Human Subjects Review Board at Central Washington University.

Testing Protocol

All swimmers underwent a standardized 600 yard warm-up to prepare for two daily individual sprint swims: a 50-yard freestyle and a 100-yard freestyle, each separated by thirty minutes. Each swim was randomized to prevent order effect. After warming-up each participant was randomly assigned one of three protocols: a control (no deep-breathing, DB_{NO}) or a deep-breathing protocol, either 30sec (DB₃₀) or 2min (DB₂). Each deep-breathing procedure was performed once for both the 50-yard and 100-yard distance. A few microliters of arterialized capillary blood were drawn to determine blood lactate immediately after each sprint. Blood lactate concentration was determined enzymatically using a lactate analyzer (LactatePro, Australia). A cool-down of 300 yards ended each sprint swim. After cool-down the swimmers performed 30min of passive rest. Participants would then re-warm up to complete the second sprint. In order to eliminate an ordering effect, all swims and deep-breathing procedures were counter balanced between subjects. All swims were recorded using an iPad (Apple, CA) strategically placed at each end of the pool. iPad one was placed at the start and iPad two was placed at the end of the lane, opposite the swim start, to record biomechanical aspects of each swim, including stroke rate, stroke length, and number of strokes, and number of breaths per sprint. Swim Coach Plus HD (Zappasoft, Australia) iPad application was used to analyze all parameters of the swims. Two of the four remaining sprint swims were performed on day two, with the remaining two sprint swims, and last deep-breathing procedures, performed on the third and final day of testing, for a total of 6 swims for each participant.

Deep-Breathing Procedure

Two experimental deep-breathing procedures were utilized, one for 30 seconds and one for 2 minutes. Each cycle (inhalation and exhalation) of deep-breathing lasted for 5sec, with a 2sec deep inhalation and 3sec of deep exhalation. Each cycle of deep-breathing was visually guided by hand raising for 2sec and

lowering the hand for 3sec in accordance with a digital pace clock. After deep-breathing, subjects had 30sec of passive rest to prepare for the start of the sprint.

Statistical Analysis

All Data was analyzed using SPSS (IBM v.25). Data are expressed as means \pm standard deviation (SD). Comparisons between the three within subjects conditions, no deep-breathing (DB_{NO}), 30sec deep-breathing (DB₃₀), and 2min of deep-breathing (DB₂), was made using a one-way ANOVA. An alpha of 0.05 was pre-set and results were deemed statistically significant at this level.

Results

Seven female subjects completed all experimental trials. Dependent variables - time, velocity, lactate, stroke count, stroke rate, stroke length, and number of breaths - for all three trials are displayed in Table 1 for the 50-yard and the 100-yard freestyle swims.

Table 1. Dependent variables for all seven female subjects (mean \pm SD) for control conditions - no deep breathing (DB_{NO}) and each of the experimental conditions - thirty seconds deep-breathing (DB₃₀) and two minutes deep-breathing (DB₂), for the 50-yard freestyle & 100-yard freestyle.

Measure	DB _{NO}	DB ₃₀	DB ₂
Time 50 (sec)	28.45 \pm 1.90	28.18 \pm 1.59	28.85 \pm 2.21
Time 100 (sec)	61.73 \pm 4.33	61.54 \pm 5.11	62.15 \pm 5.52
Average Velocity 50 (yards/sec)	1.75 \pm 0.12	1.77 \pm 0.10	1.73 \pm 0.13
Average Velocity 100 (yards/sec)	1.62 \pm 0.11	1.63 \pm 0.13	1.62 \pm 0.14
La+0min 50	2.90 \pm 1.58	3.81 \pm 1.06	3.04 \pm 1.49
La+0min 100	3.94 \pm 2.65	4.59 \pm 2.70	5.11 \pm 3.19
Stroke Count 50 (strokes/50)	31.00 \pm 2.08	31.00 \pm 1.91	30.71 \pm 2.29
Stroke Count 100 (strokes/100)	63.43 \pm 3.74	63.57 \pm 4.39	64.14 \pm 5.21
Stroke Rate 50 (Strokes/sec)	1.18 \pm 0.20	1.16 \pm 0.16	1.16 \pm 0.19
Stroke Rate 100 (Strokes/sec)	1.11 \pm 0.20	1.09 \pm 0.19	1.11 \pm 0.20
Stroke Length 50 (yards/stroke)	1.53 \pm 0.26	1.56 \pm 0.22	1.56 \pm 0.26
Stroke Length 100 (yards/stroke)	1.50 \pm 0.25	1.52 \pm 0.23	1.49 \pm 0.23
# of Breaths (50)	7.00 \pm 2.00	6.29 \pm 1.80	6.57 \pm 0.79
# of Breaths (100)	23.50 \pm 3.55	24.13 \pm 3.80	23.75 \pm 4.71

Values are means \pm standard deviation. * Significant difference: P < 0.05.

50 Freestyle

Average velocity for the 50-yard freestyle was higher for the DB₃₀ compared to DB_{NO} (1.77 ± 0.10 yards/sec vs. 1.76 ± 0.12 yards/sec $p=0.37$, respectively) however the DB₂ resulted in slower average velocity when compared to DB_{NO} (1.74 ± 0.13 yards/sec $p=0.23$). Time improvements in performance were observed for DB₃₀ over DB_{NO} (-0.27sec) however, the DB₂ protocol resulted in a slower performance when compared to DB_{NO} and DB₃₀ (+0.40) (Figure 1).

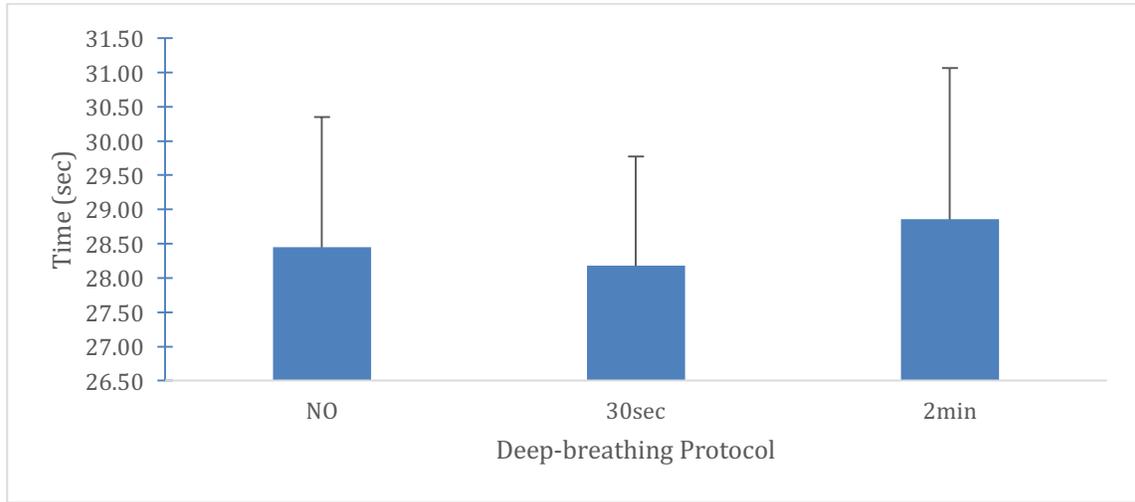


Figure 1. Mean times for the 50-yard freestyle for all seven female swimmers for each deep-breathing protocol.

Lactate values immediately after swims were higher for DB₃₀ & DB₂ trials (DB₃₀ 3.8 ± 1.06 mmol/L, $p=0.23$, DB₂ 3.0 ± 1.49 mmol/L, $p=0.29$) compared to control (DB_{NO} 2.9 ± 1.58 mmol) (Figure 2).

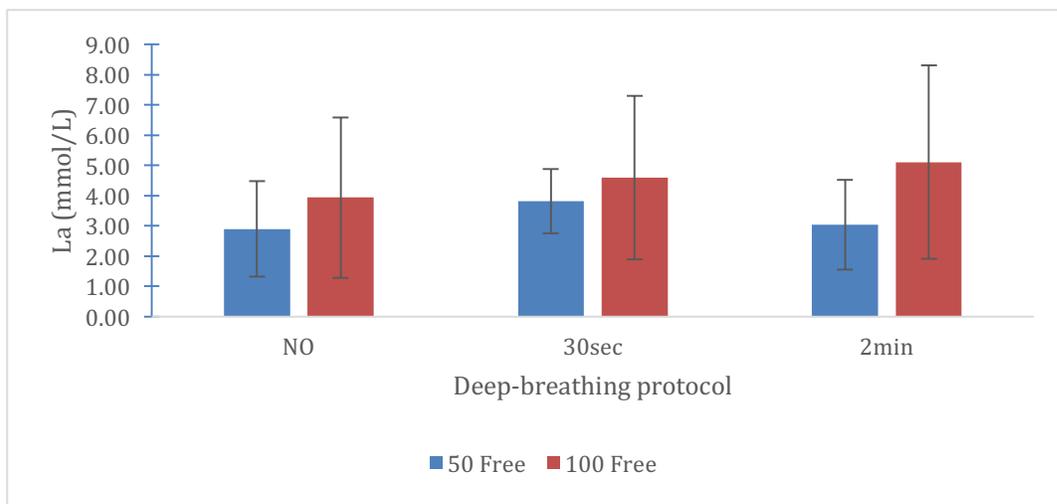


Figure 2. Mean lactate values for the 50-yard & 100-yard freestyle for all seven female swimmers for each deep-breathing protocol.

There were no differences observed for stroke count or stroke rate for either DB_{NO} (31.0 ± 2.08 strokes/50; 1.17 ± 0.20 strokes/sec) DB₃₀ (31.0 ± 1.91 strokes/50; 1.15 ± 0.16 strokes/sec) and DB₂ (30.7 ± 2.29 strokes/50; 1.16 ± 0.19 strokes/sec). There was, however, a slight improvement in stroke length between DB_{NO} (1.53 ± 0.26 yards/stroke) and DB₃₀ (1.56 ± 0.22 yards/stroke, p=0.32) as well as an improvement in stroke length for DB₂ (1.56 ± 0.26 yards/stroke, p=0.08).

Lastly, the number of breaths was not significantly different in the DB₃₀ when compared to the DB_{NO} (6.29 ± 1.80 vs. 7.00 ± 2.00, respectively), while DB₂ resulted in a similar amount of breaths taken (6.57 ± 0.79) compared to DB_{NO}.

100 Freestyle

Average velocity for the 100-yard freestyle was the same for the DB₃₀ trials compared to DB_{NO} (1.63 ± 0.13 yards/sec vs. 1.63 ± 0.11 yards/sec, p=0.62, respectively) with slower average velocity in the DB₂ trials (1.62 ± 0.14 yards/sec p=0.63). Time improvements in performance were seen for DB₃₀ compared to DB_{NO} (-0.19sec) and slower times for DB₂ compared to DB_{NO} (+0.42sec)

Lactate values immediately after swims were higher for DB₃₀ & DB₂ trials (DB₃₀ 4.5 ± 2.70 mmol/L, DB₂ 5.11 ± 3.19 mmol/L) compared to control (DB_{NO} 3.9 ± 2.65 mmol), (Figure 2).

There were no statistical differences observed for stroke count or stroke rate for either DB_{NO} (63.4 ± 3.74 strokes/100; 1.11 ± 0.20 strokes/sec) DB₃₀ (63.6 ± 4.39 strokes/100; 1.09 ± 0.19 strokes/sec) and DB₂ (64.1 ± 5.21 strokes/100; 1.11 ± 0.20 strokes/sec). There was a slight improvement in stroke length between DB_{NO} (1.50 ± 0.25 yards/stroke) and DB₃₀ (1.52 ± 0.23 yards/stroke, p=0.32) and observed less distance/stroke for DB₂ (1.49 ± 0.23 yards/stroke, p=0.86).

Lastly, the number of breaths was not significantly different in the DB₃₀ when compared to the DB_{NO} (24.13 ± 3.80 vs. 23.50 ± 3.55, respectively), while DB₂ resulted in a similar amount of breaths taken (23.75 ± 4.71) compared to DB_{NO}.

Discussion

Thirty Seconds Deep-Breathing

The main finding of this study revealed increased velocity and an improved time to completion after the DB₃₀ for both the 50 and 100-yard freestyle swims. Although no statistical difference was detected, a mean time improvement of 0.27sec would have competition ramifications and are similar to the time improvements observed by Jacob et al. (2015) for the 50-meter freestyle. Individual performance improvements for the current study ranged from 0.10sec to 1.1sec under DB₃₀ conditions and all but one participant improved. The one non-responder added 0.6sec.

To date, no study has established the effects of deep-breathing on a 100-yard swimming performance. Although not statistically significant, an improvement of 0.19 could result in a competitive advantage. Seventy one percent of the participants responded positively to the DB₃₀ protocol in the 100-yard trials. The two non-responders added 0.8sec & 3.2sec.

Studies have observed elevated blood lactate response due to deep breathing (Maddock, 2001; Fujii et al., 2015). This study indicated an increased lactate production for both the 50 and 100-yard trials immediately post swim. Changes in blood lactate levels will follow changes in expired CO₂ levels demonstrating that lactate and CO₂ are closely linked (Anderson & Rhodes, 1991). Deep-breathing will drop baseline CO₂ levels and thereby signal the aerobic energy system to abate by down-regulating the pyruvate dehydrogenase (PDH) complex (Fujii et al., 2015). To compensate for the down-regulation of aerobic pathways, anaerobic systems will be up-regulated. Low CO₂ levels have been shown to up-regulate phosphofructokinase (PFK) activity (Fujii et al., 2015) thus increasing lactate production. The current study agrees with the findings of Maddock, and Fujii as lactate levels were higher for DB₃₀ compared to control (DB_{NO}) (Figure 2).

While stroke count (SC) and stroke rate (SR) were similar across all DB protocols, stroke length (SL) was improved in the DB₃₀ trials, though not statistically significant. Improved distance per stroke (SL) is considered a major factor for improved swimming efficiency (Smith et al., 2002) and the SL improvements in this study would equate to a 5.5cm lead in the 50-yard event and a 3cm lead in the 100-yard event. These results are contrary to Jacobs who determined no difference in SL from their DB protocol (Jacob et al., 2015).

Slower swimming speeds have been shown when turning the head to breath (Psycharakis & McCabe, 2011), however, this study found no contribution to improved times as the number of breaths remained similar across all DB trials (Table 1).

Two Minutes Deep-Breathing

Two minutes of deep-breathing (DB₂) negatively affected 50-yard freestyle performance when compared to baseline conditions (DB_{NO}) resulting in slower velocities and therefore slower swim times (Figure 1). A 0.35sec increase in time would result in a competitive disadvantage in the 50 freestyle. Under normal exercise conditions there is an increase in extra cellular levels of CO₂ which signals vasodilation, sanctioning a decrease in peripheral resistance, and positively affecting performance. However, a few minutes of DB causes excessively low CO₂ levels and has shown to vasoconstrict relevant blood vessels increasing peripheral resistance and negatively affecting performance (Gilbert, 1999). Additionally, low CO₂ reduces sympathetic vagal activity and, consequently, reduces blood pressure (Joseph et al., 2005; Mori et al., 2005). If vasodilation and an increase in blood

pressure are normally seen at exercise onset, it could be that performance is compromised in the 50 freestyle where vasoconstriction and low blood pressure concurrently present themselves explaining the slower times associated with DB₂. Furthermore, a loss of 2% blood flow occurs for every 1mmHg drop in CO₂ pressure (Gardner, 1996). Indeed, some participants reported minor perceptions of light-headedness prior to their swim trials which could affect their swims.

While DB₂ resulted in slower times for the 50-yard swims, DB₂ also revealed slower velocities and an increase in time for the 100-yard swims, respectively. All participants superseded the :55sec threshold where the aerobic system starts to dominate over the declining anaerobic system (Rodríguez & Mader, 2011). The same up-regulation of PFK and down-regulation of PDH from DB (Chin et al, 2007; Chin et al., 2010; Jacob et. al., 2008) would explain the poorer performance in the DB₂ 100-yard swims.

Higher lactate values post swim for DB₂ over control in the 100-yard trials suggest up-regulation of the anaerobic system pre-swim from DB (Chin et al, 2007; Chin et al., 2010; Jacob et al., 2008). Despite the increase in anaerobic metabolism pre-race, the down-regulation of aerobic metabolism due to DB (Sakamoto et al., 2014) suppressed performance in the 100 because of the length of the swim trial – i.e., being longer than the proposed :55sec where aerobic metabolism begins to dominate in its role in performance.

As seen in the DB₃₀ swims, SC and SR were similar for DB₂ swims in both the 50 and 100-yard trials. Distance per stroke (SL) was slightly lower for DB₂ compared to DB_{NO} 100-yard swims indicating a reduction in swimming efficiency.

As in the DB₃₀ protocol, the number of breaths taken revealed no indications of performance benefit or disadvantage from the DB₂ trials as the number of breaths remained similar across all 100-yard swims (Table 1).

Conclusions

In conclusion, this study showed that 30 seconds of deep-breathing prior to a 50 or 100-yard freestyle can improve race performance in NCAA collegiate female swimmers. Lowering baseline CO₂ levels prior to a race can delay the onset of perceived fatigue, improved race times, and provide the swimmer with a competitive advantage. Two minutes of deep-breathing, however, could negatively affect 50 and 100-yard swimming performances. Further studies should investigate the effects of 30 seconds of deep-breathing on longer races distances, i.e. 200 yard freestyle. In addition, a one-minute deep-breathing protocol on swim races should be investigated.

Limitations

Homogeneity of the sample population could have contributed to the large performance variability minimizing the ability to detect a performance statistical difference from the two deep-breathing protocols. Future studies should look at a more homogeneous group of athletes. Furthermore, the limited number of subjects could have contributed to a low statistical power.

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