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Stretching After an In-Water Warm-Up Does Not Acutely Improve Sprint Freestyle Swim Performance in DIII Collegiate Swimmers

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ABSTRACT

Topics in Exercise Science and Kinesiology Volume 2: Issue 1, Article 11, 2021. Stretching, as part of a warm-up prior to competition, has been used as a method to enhance performance in swimming and other sports, but its efficacy as a potential ergogenic aid remains understudied. This study's purpose was to determine if acute static stretching or a dynamic warm-up, following an in-water swim-specific warm-up, improved sprint freestyle swim performance in collegiate swimmers**.** NCAA Division III swimmers (n=15, 67% female) participated in three testing protocols. In each protocol, participants did an in-water warm up and either a dynamic warmup (DW), static stretching warmup (SS), or no stretching (CON) routine followed by three, 100-yard freestyle sprints, each performed four minutes apart. Swim times were recorded for the first and second 50-yard splits and for the full 100 yards in each trial. Repeated-measures analysis of variance and effect sizes were used to assess differences across protocols. Average performance was significantly faster for CON compared to DW for the first 50-yard split (mean difference ~0.47 seconds, p=0.044) and total 100-yard time (mean difference ~0.77 seconds, p=0.017), with medium effect sizes for both. No differences were observed between SS and the other protocols. Adding acute stretching or dynamic warm-up, following an in-water warm-up, either did not improve or was associated with poorer 100-yard freestyle swim performance than solely performing an in-water warm-up. Swimmers should carefully evaluate their warm-up routines and consider a focus on in-water warm-ups for maximizing sprint swim performance.

KEY WORDS: Swimming, static, dynamic, calisthenics, athletic performance

INTRODUCTION

Swimming is an increasingly popular and competitive sport in the United States. According USA Swimming, there has been a 21% increase in year-round swimmers that are enrolled in competitive club swim teams between 2008 and 2019 (28). As swimming has increased in popularity, the need for scientifically supported methods to enhance performance has increased as well. In competitive swimming, fractions of a second often determine the winner of a race. Many swimmers use specialized swim suits, caps, and/or body shaving to decrease drag and thereby improve performance (7, 11, 26). Swimmers also rely on warm-up routines to prepare themselves to compete at their best. Active swimming warm-ups can increase body and muscle temperature to improve performance (25, 29). Swimmers often do in-water warmups including a variety of swim-specific drills, strokes, kicking, and pulling. Warm-up protocols can include on-land components before or after in-water warm-ups. On-land warm-ups are commonly composed of stretching, strength, calisthenics, and activation exercises (20). If and how such warm-up routines affect swim performance, and what should be included in a warm-up, is of high interest to those looking to optimize races or practices.

Stretching is commonly used prior to competition and practice. Stretching routines often fall into two categories, dynamic or static (or a combination of both). A dynamic stretching warm-up involves actively moving joints and muscles through their range of motion, usually consisting of functional-based stretches and actions, which may also use sport-specific movements to prepare the body for activity (18). Conversely, static stretching involves holding a joint at the end of the joint's range of motion for 10-60+ seconds (31).

Static stretching may affect athletic performance in several ways. One way it is thought to improve performance is by decreasing tendon and aponeurosis stiffness. While some research has related decreased stiffness to ease of movement and increased muscle performance (15), other work has found that static stretching of the biceps brachii was detrimental to force production of concentric isokinetic muscle contraction (6). From this specific mechanism, static stretching could hurt or help performance depending on context. Additionally, static stretching acutely and chronically increases range of motion, potentially allowing more effective movement during sport (23, 24). Such beliefs about static stretching have rendered it a popular feature of warm-up routines (30). However, a recent review found that static stretching significantly impeded muscular or sport performance especially when performed for extended durations or at higher intensities (e.g., to pain threshold), possibly by a negative impact on balance, agility, and peak power generation (2, 14). Thus, static stretching may only be beneficial as part of a warm-up in sports that require flexibility, such as gymnastics, dance, and possibly swimming (3).

Dynamic warm-ups increase muscle and body temperature and have been shown to affect post activation potentiation, which increases the rate of cross bridge cycling and may improve muscular force production (9, 12). In past research, dynamic warm-ups has been shown to increase peak power in isolated knee extensors (16) and have resulted in improvements in shuttle run time, medicine ball throws, and jumping in US military troops (17). On the other hand, dynamic warm-ups have been shown to decrease muscular endurance when the duration or intensity is too high (24), thereby providing a potential mechanism by which a dynamic warm-up could actually impede performance.

Acute stretching and dynamic warm-ups appeal as potential ergogenic aids due to their inexpensive nature and accessibility to swimmers of all ages and skill/training levels. While past research highlights potential advantages and disadvantages of static stretching and dynamic warm-up for muscular performance, we are aware of only one study to date that has evaluated their effects on swim performance (13). In this previous study, sub-elite, collegiate female swimmers (n=14) completed a warm-up (walk/jog for 5 minutes) and one of four conditions (control [no further warm-up], static stretching, dynamic/ballistic warm-up, or in-water 1,200-meter swim warm-up) prior to performing 50-meter freestyle and 50-meter breaststroke sprints. The authors found a significant improvement in freestyle and breaststroke performance with the in-water warm-up and the dynamic warm-up compared to control and static stretching conditions. However, this study did not evaluate a potential additive effect of in-water warm-ups with stretching or dynamic warm-up, nor did it evaluate swim distances other than 50 meters.

Given the sparse research examining the effect of acute stretching or dynamic warm-up on swim performance, this study's purpose was to determine the effect of acute static stretching or dynamic warm-up, performed after an in-water warm-up, on swim performance in Division III collegiate swimmers.

METHODS

Participants

Potential participants were eligible for this study if they were 18 years or older, a Division III collegiate swimmer, and did not have any current injuries that would prevent their ability to complete the study protocols. Participants were fully informed of the study procedures and provided written informed consent prior to beginning the study, and the Alma College Institutional Review Board approved all study procedures (IRB #R_2ZNOhp2unWDdxdy). This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (19).

Participants (n=15) consisted of three breaststroke specialists, two butterfly specialists, two backstroke specialists, and six freestyle specialists. Additionally, there were two participants who trained for the individual medley races, indicating that they competed in all strokes during the collegiate competition season. Participants also self-reported what training group they train with during the season. Seven participants identified as sprinters (50-yard and 100-yard events), five identified as mid-distance swimmers (trained for 200-yard events), and three identified as distance swimmers (500-yard and 1,650-yard freestyle). Demographics of the participants can be found in Table 1.

Table 1. Participant demographics.

	Total (n=15)	**Female (n=10)**	**Male (n=5)**
Age (years)	19.5±1.4	19.6±1.3	19.2±1.6
Height (m)	1.72±0.07	1.70 ±0.06	1.77±0.05
Weight (kg)	72.4±9.0	71.3±8.3	75.0±9.8
Years of collegiate swimming	2.3±1.1	2.4±1.0	2.0±1.2
Years of competitive swimming	10.4±3.0	11.6±2.2	7.8±2.8
Personal best 100-yard freestyle (seconds)	56.65±4.71	59.00±3.24	52.33±4.40

Data are shown as mean ± standard deviation.

Protocol

Participants were scheduled for three sessions, with 2-5 days between each, at the same time of day (i.e., afternoon, evening). Participants were asked to maintain their current, sleep, exercise and diet routines throughout the study. Sessions were scheduled to both avoid lingering effects of fatigue as well as be close enough together in time to minimize any potential changes in fitness across the study period.

Before participants arrived at the pool, they completed a demographics survey. Participants self-reported age, height, weight, sex, year in college, total number of years swimming competitively, total number of years that they had been swimming in college, any previous/current injuries, personal best 100-yard freestyle time, training group (sprint, mid-distance, or distance), and strokes (freestyle, breaststroke, butterfly, backstroke, or individual medley) that they specialized and trained for during the previous competitive swimming season.

When the participants arrived at the pool for testing, they completed a visual analog "state of being" survey. Participants subjectively described their level of stress, soreness, tiredness, and overall wellbeing. Next, participants began the in-water warm-up. The pool used for this study was a standard 25-yard pool with an average temperature of 25.6-26.7 degrees Celsius. The in-water warm-up consisted of a 400-yard swim, 300-yard pull (arms engaged, legs resting), and 200-yard kick (legs engaged, arms holding kickboard). Then, the participants were able to adjust the diving block wedges to the appropriate position and practiced their start by doing two, 12.5-yard sprints off the block on the researcher's call.

Participants were assigned a protocol for each day, either the no stretching protocol (CON), static stretching protocol (SS), or the dynamic warm-up (DW) protocol. This process occurred using a random number generator to mitigate any potential ordering effect.

The CON protocol consisted of eight minutes of quiet sitting on an exercise mat. The stretches included in the SS and DW protocols can be found in Table 2, and they were mirrored off of stretching procedures completed by McMillian et al. (17). For the SS protocol, participants performed each of the nine exercises once for a 20-second duration for each side of the body. The DS protocol contained 10 stretches that were to be repeated 10 times per exercise.

The swim performance testing began within five minutes after the CON, SS, or DW protocols were completed. The swim performance testing consisted of three, 100-yard freestyle sprints at maximal effort, separated by roughly three minutes of rest between sprints. The sprints were video recorded using an iPhone 11 (Apple, Inc. Cupertino CA), and times were determined via post-testing analysis using Adobe Premier Pro, allowing videos to be analyzed frame-by-frame, for an accuracy in timing of ±0.033 seconds. Researchers manually timed the sprints as a backup in case of video failure, starting when the starter said "go" and ending when the participants' fingertips touched the wall.

Table 2. Stretches performed in the static and dynamic warm-up protocols.

Stretches performed during static protocol (20 seconds of each)	**Activities performed during dynamic protocol (10 repetitions of each, slow-moderate cadence)**
Overhead pull – Raise one arm overhead and place behind head. Grab raised arm below the elbow with other arm, pulling to the side while leaning the body away from the raised arm. Repeat on other side of body.	***Bend and reach –*** With arms high overhead, squat and reach between legs.
Turn and reach – With arms extended to sides, rotate trunk to one side while keeping the hips and head facing forward. Repeat on other side of body.	***Rear lunge and reach –*** With hands on hips, step backward with one leg while bending front knee and raising arms overhead. Return to original position, and repeat on other side of body.
Rear lunge and reach – With arms overhead, step backward with one foot. Repeat on other side of body.	***Turn and reach –*** With arms extended at sides, turn in one direction while keeps hips facing forward. Return to original position, and repeat on other side of body.
Hamstring stretch – Step forward with one foot, and bend forward at the waist. Repeat on other side of body.	***Squat –*** With hand on hips, squat until thighs are parallel with ground.
Calf stretch – Step forward 8-10 inches with one foot, and raise toes of this food upward. Grasp sides of foot with both hands. Repeat on other side of body.	***Rower*** – Lying supine with arms overhead, raise to a seated position while bending knees to chest.
Quadriceps stretch – Lying on one side of body, bend knee on side of the body facing up, and grab ankle with the arm on the same side. Repeat on other side of body.	***Power jump –*** With arms high overhead, squat and reach toward the ground. Then, jump while raising arms back overhead, landing in squat position.
Posterior hip stretch – Lying supine, cross one ankle on top of the opposite thigh. Pull knees toward the shoulder on opposite side of body as the crossed ankle. Repeat on other side of body.	***Prone row –*** Lying prone with arms overhead, raise chest slightly off ground while pulling hands to shoulder level.
Trunk flexion stretch – Hands and knees on ground, bend knees to sit back into legs while extending arms to front.	***Push-up –*** Lying prone with hands under shoulders, straighten arms while pushing body upward, with toes (or, if necessary, knees) as pivot point.
Trunk extension stretch – Lying prone with hands under shoulders, straighten elbows while keeping thighs and hips on ground.	***Windmill –*** With arms extended sideways, squat while bending forward and reaching hand down toward opposite foot. Return to original position, and repeat on other side of body.
	Side lunge and reach – With arms overhead, lunge to side while lowering the hands to the lower leg. Return to original position, and repeat on other side of body.

Between sprints, participants passively recovered (asked not to perform stretching, jumping, or other activity) but were able to exit the pool and reset a minute prior to the beginning of the next sprint. Additionally, participants were able to drink water ad libitum between sprints. After completion of the three sprints, the participants completed a 200-yard swimming cool-down to minimize soreness and eliminate lactic acid accumulation that may impede performance in future sessions.

Statistical Analysis

Total times for each 100-yard sprint, as well as the times for the first and second 50-yard splits of each sprint, were measured to the nearest hundredth of a second. Peak performance was determined as the fastest time of the three sprints, and average performance was determined as a mean of the three sprint times. Additionally, to evaluate fatigue, the difference between the fastest and slowest sprint times (DiffFS), and the difference in completion time between the first and third sprints (Diff13), were calculated. These variables (peak performance, average performance, DiffFS, Diff13) were compared across the CON, SS, and DW conditions using repeated-measures analysis of variance, with a least significant difference correction used for post hoc, pairwise comparisons. We also ran repeated-measures analysis of covariance tests, controlling first for stroke specialization and then for distance specialization, but the results were identical to the initial test; thus, only results from the initial repeated-measures analysis of variance are presented. A p-value of $p \leq 0.05$ was used to denote statistical significance, and $0.05 < p. \leq 0.10$ was used to denote non-significant trends.

Effect sizes (ES) were calculated as the difference in means between conditions divided by the standard deviation of the differences between conditions, and they were interpreted as ES<0.20 = trivial, 0.20≤ES<0.50 = small, 0.50≤ES<0.80 = Medium, 0.80≤ES<1.30 = Large, and ES>1.30 = very large (5). Using the G*Power analysis software (version 3.0.10; Kiel, Germany), it was determined that our sample size of n=15 allowed for statistically significant findings with a minimum effect size of 0.50 when using an alpha of 0.05 and a minimum power of 0.80 as suggested by Cohen (5). Analyses were conducted in SPSS version 24.0 (IBM Corp., Armonk NY) and Microsoft Excel 2016 (Microsoft Corp., Redmond WA).

RESULTS

Times for the 100-meter sprints ranged from 54.48-73.51 seconds. Results of the trials for average performance, peak performance, and rate of fatigue (Diff13 and DiffFS) are shown in Table 3. Statistical testing revealed a significantly faster 100-yard average performance for CON compared to DW (difference ~0.77 seconds, p=0.017), with a medium effect size (Table 4). When comparing the peak performance in the 100-yard freestyle set, there was a non-significant trend toward faster times for CON compared to DW (difference ~0.80 seconds, p=0.094), with a small effect size. No significant pairwise differences were present for peak or average performance between CON and SS or between DW and SS, and all effect sizes were small or trivial. Additionally there were no differences in fatigue (Diff13 or DiffFS) among the three protocols, all with small or trivial effect sizes.

When analyzing the first 50-yard split, average performance was significantly faster for CON compared to DW (difference ~0.47 seconds, p=0.044; medium effect size), and there was a non-significant trend toward faster average performance for CON compared to SS (difference ~0.28 seconds, p=0.077; small effect size). There was no difference and small/trivial effect sizes among the three protocols for peak performance, Diff13, or DiffFS. For the second 50-yard freestyle split, there were no significant differences or trends across the three protocols for any of the outcome variables assessed, and effects sizes were small or trivial.

Table 3. Times for 100-yard sprints and 50-yard splits for the control and stretching conditions.

	Control	**Dynamic warm-up**	**Static stretch**
100-yard sprint			
Peak performance	61.84 (4.53)	62.64 (4.66)^	62.39 (4.53)
Average performance	62.57 (4.56)	63.34 (4.60)*	62.99 (4.22)
Difference fast to slow trial	1.52 (1.31)	1.45 (1.31)	1.24 (1.07)
Difference first to third trial	1.10 (1.64)	0.69 (1.54)	0.47 (1.25)
First 50-yard split			
Peak performance	29.14 (2.02)	29.66 (2.30)	29.50 (1.71)
Average performance	29.68 (1.89)	30.15 (2.26)*	29.96 (1.84)
Difference fast to slow trial	1.11 (0.65)	0.94 (0.75)	0.90 (0.74)
Difference first to third trial	0.68 (0.92)	0.47 (0.97)	0.35 (1.11)
Second 50-yard split			
Peak performance	32.35 (2.79)	32.76 (2.42)	32.45 (2.55)
Average performance	32.89 (2.77)	33.18 (2.40)	33.02 (2.46)
Difference fast to slow trial	1.14 (0.87)	0.88 (0.71)	1.23 (0.87)
Difference first to third trial	0.36 (1.13)	0.41 (0.89)	0.20 (1.21)

Times are displayed in seconds, as mean (standard deviation). *Indicates significant difference from Control ($p \leq 0.05$). ^Indicates non-significant trend toward difference from Control ($0.05 < p \leq 0.10$).

Table 4. Effect sizes for differences in swim performance among control, dynamic warm-up, and static stretching conditions.

	Control – Dynamic	**Control – Static**	**Dynamic – Static**
100-yard sprint			
Peak performance	0.46	0.32	0.35
Average performance	0.70*	0.34	0.36
Difference fast to slow trial	0.04	0.22	0.16
Difference first to third trial	0.19	0.34	0.13
First 50-yard split			
Peak performance	0.45	0.43	0.12
Average performance	0.57*	0.49	0.20
Difference fast to slow trial	0.12	0.18	0.07
Difference first to third trial	0.11	0.25	0.20
Second 50-yard split			
Peak performance	0.45	0.08	0.29
Average performance	0.44	0.11	0.15
Difference fast to slow trial	0.23	0.11	0.36
Difference first to third trial	0.04	0.09	0.15

Control: no stretching condition. Dynamic: dynamic warm-up condition. Static: static stretching condition. *Represents medium or larger effect size.

DISCUSSION

Stretching and land-based dynamic activities are commonly used to supplement in-water warm-ups for competitive swimmers at every age. Due to limited space in pools, especially in non-elite settings, swim meets typically allow for in-water warm-up time prior to competition start, with the possibility of a shorter in-water warm-up immediately prior to a swimmer's race. However, meets often use all pool lanes, so many swimmers have limited in-water warm-up opportunities following the initial warm-up. For this reason, the time between an in-water warm-up and competition can be filled with land-based stretching or dynamic warm-ups. These do not require any materials and can be performed safely on a crowded pool deck. In this study, we simulated a competition setting through an in-water warm-up followed by static stretching (SS), dynamic warm-up (DW), or rest (CON) as competitive swimmers would on a competition day.

This study found that adding static stretching to an in-water warm-up did not benefit swim performance, and that adding a dynamic warm-up was associated with poorer average 100-yard, freestyle swimming performance in DIII collegiate swimmers, compared to completing an in-water warm-up only. The difference in average performance across the three trials shows that decrements in performance with the dynamic warm-up persisted over 10-20 minutes following stretching.

Our results are in some ways similar to that of the previous swim study by Kafkas et al. (13). That study found no beneficial effect of a dynamic warm-up and a decrement in performance with static stretching (performed in 30 second bouts). This was compared to an in-water warm-up only, prior to 50-meter freestyle and breaststroke sprints. While our studies together do not assert which type stretching or warm-up may hinder sprint swim performance, they suggest that there is no added benefit, and possibly a performance decrement, when static stretching or a dynamic warm-up is used in place of or in addition to an in-water warm-up. Our study builds off the work of Kafkas et al. (13) by showing improved performance over multiple trials, at a longer distance, in a mixed sample including female and male athletes, and across a group of swimmers with different specialty strokes and distances.

Previous research in non-swimming activities shows that dynamic warm-ups may increase fatigue and thereby lower muscular performance (24), and our study similarly found a sustained performance decrement with the dynamic warm-up. Thus, it may not be advisable to complete dynamic warm-ups alongside an in-water warm-up prior to sprint swimming, especially close in time to when the event will take place. Additionally, current literature suggests that static stretching is not advantageous for strength/sprint athletes due to a decrease in endurance and acute maximal strength (8, 14, 21). Kafkas et al. (13) supports this as the slowest 50-meter races followed a bout of static stretching. The present study found no benefit from static stretching, with point estimates non-significantly favoring the in-water warm-up only condition. Together, these findings suggest that stretch duration may impact swim performance. This study consisted of 20-second bouts of static stretching, whereas Kafkas used 30-second bouts. While both durations fall within ACSM's recommended 10-30 second duration (10), the longer stretching by Kafkas et al. resulted in larger performance decrements. This suggests that any potential gains in acute flexibility by static stretching are unfavorably offset by changes in tendon/aponeurosis stiffness or other mechanisms and ultimately may hinder peak sprint swim performance. Future studies should assess different bout durations of static stretching to further elucidate if static stretching in any duration is suitable prior to sprint swimming.

Previous studies have tried to identify optimal swim warm-up strategies in the pool to maximize performance. While each swimmer is biologically different and likely requires a different volume of warm-up prior to competition, a previous study found both short aerobic warm-ups (100 yard) and the regular aerobic warm-ups selected by the swimmer (~1,200-1,300 yards) resulted in similar performance in a 100-yard freestyle sprint (1). This leads us to believe that the 950-yard warm-up used in the present study was sufficient for most, if not all of the participants in our sample.

We did not measure physiologic variables such as heart rate, lactate, or oxygen consumption or psychological variables such as concentration or focus during or after our trials, so our study cannot illuminate potential mechanisms underpinning improved swim performance when using an in-water warm-up only as compared to an in-water warm-up and stretching/land-based warm-up. However, past research suggests that aerobic, activity-specific warm-ups initiate multiple physiologic mechanisms that may be advantageous for swimmers, including a decreased movement resistance of muscle and joints, greater oxygen release from hemoglobin and myoglobin, increased speed of metabolic reactions, and increased nerve conduction rate due to an increase in body temperature (4). These mechanisms appear to occur even in the absence of a stretching routine. Warm-ups can also have non-temperature effects such as increased blood flow to the working muscles, elevated baseline oxygen consumption, increased post-activation potentiation, and even psychological effects to prepare swimmers for competition (4). In-water warm-ups may also increase heart rate, ventilation, and flexibility to ultimately improve swim performance (1). Finally, warm-ups may provide a psychological enhancement as a time for concentration and focus prior to exercise which may prime the athletes for exercise, regardless of the stakes of the exercise (27). Whether the duration or type of warm-up affect these psychological or physiological mechanisms related to improved performance remains to be elucidated in future work.

The in-water warm-up protocol in our study resulted in a 0.77 second, (1.2%) improvement in performance compared to the in-water plus dynamic stretching warm-up. For context, this improvement is slightly smaller than performance improvements seen in past research with specialized swim suits/caps and with body shaving (7, 11). However, for the practitioner or coach looking at low-cost, feasible methods for optimizing swim performance, such strategies (warm-up choice and equipment/body preparation) used in combination may result in substantial performance improvements.

Our study had several limitations that should be noted when considering our results. Namely, our sample size, while in line with past work, did not allow for sub-analyses by sex, stroke specialization, distance specialization, or number of years of competitive swimming to determine if any of these factors may influence whether stretching or land-based dynamic warm-ups affect swim performance. Additionally, fractions of a second may have meaningful practical significance, but our study was underpowered to detect changes that small in magnitude. Finally, while participants were instructed and reminded to give maximal effort, there was no external motivation (e.g., people cheering, adrenaline of a competitive environment), which may have resulted in lower peak performances and lesser rates of fatigue. Our study also had notable strengths, especially when compared to past research. First our study was able to assess performance not only in a single trial, but also to assess splits to see where performance improvements took place as well as to gauge performance over multiple trials, similar to how most swimmers would compete in swim competitions. Coaches and athletes analyze performance based on 50-yard splits to determine the quality of the race performance. We were able to determine that the improvement was in the front half of the race. Finally, the real-world nature of the study and the unique contribution of a mixed sample of males and females, distance and sprint swimmers, and specialists in different stroke types gives a good degree of generalizability to the study results. While not all swimmers consider themselves sprinters or freestyle specialists, the freestyle stroke is the most commonly trained stroke where virtually all swimmers, regardless of specialty, have a familiarity and practice with this stroke and length (100 yards). This was vividly illustrated in the recent 2020 Tokyo Olympics, where the top male swimmer (Caeleb Dressel; 5 gold medals) and female swimmer (Emma McKeon; 7 medals, 4 of which were gold) both won medals in more than one stroke type, distance, and in both relay and individual events (22). Such versatility is unusual in other sports. Therefore, although we cannot generalize our results to every swim race type or distance, our chosen stroke and distance is among the most universal to competitive swimmers and is likely to meaningfully inform swimmers how to structure warm-ups to optimize swim performance.

In conclusion, our study adds important data to an understudied field, suggesting that acute static stretching and land-based dynamic warm-ups do not improve sprint swim performance, and may actually hurt performance, when used following a swim-specific warm-up in collegiate swimmers. However, regardless of if these strategies are neutral or if they actually hurt swim performance, the available evidence suggests that swimmers should focus on in-water warn-ups when preparing for competition in freestyle sprint swimming events.

REFERENCES

1. Balilionis G, Nepocatych S, Ellis CM, Richardson MT, Neggers YH, Bishop PA. Effects of different types of warm-up on swimming performance, reaction time, and dive distance. Journal of Strength & Conditioning Research 26(12):3297-3303, 2012.

2. Behm DG, Chaouachi A. A review of the acute effects of static and dynamic stretching on performance. European Journal of Applied Physiology 111(11):2633-2651, 2011.

3. Behm DG, Kibele A. Effects of differing intensities of static stretching on jump performance. European Journal of Applied Physiology 101(5):587-594, 2007.

4. Bishop D. Warm up i: Potential mechanisms and the effects of passive warm up on exercise performance. Sports Medicine 33(6):439-454, 2003.

5. Cohen S. *Statistical power analysis for the behavioral sciences*. 2 ed. Hillsdale (NJ): Lawrence Erlbaum Associates; 1988.

6. Evetovich TK, Nauman NJ, Conley DS, Todd JB. Effect of static stretching of the biceps brachii on torque, electromyography, and mechanomyography during concentric isokinetic muscle actions. Journal of Strength & Conditioning Research 17(3):484-488, 2003.

7. Foster L, James D, Haake S. Influence of full body swimsuits on competitive performance Procedia Engineering 34(2012):712-717, 2012.

8. Fowles JR, Sale DG, MacDougall JD. Reduced strength after passive stretch of the human plantarflexors. Journal of Applied Physiology 89(3):1179-1188, 2000.

9. Fredrick GA, Szymanski DJ. Baseball (part i): Dynamic flexibility. Journal of Strength & Conditioning Research 21(1):21-30, 2001.

10. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, Nieman DC, Swain DP, American College of Sports M. American college of sports medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. Medicine and Science in Sports and Exercice 43(7):1334-1359, 2011.

11. Gatta G, Zamparo P, Cortesi M. Effect of swim cap model on passive drag. Journal of Strength & Conditioning Research 27(10):2904-2908, 2013.

12. Houston ME, Grange RW. Myosin phosphorylation, twitch potentiation, and fatigue in human skeletal muscle. Canadian Journal of Physiology and Pharmacology 68(7):908-913, 1990.

13. Kafkas A, Eken O, Kurt C, Kafkas ME. The effects of different stretching and warm-up exercise protocols on 50-meter swimming performance in sub-elite women swimmers. Isokinetics and Exercise Science 27(2019):289-297, 2019.

14. Kokkonen J, Nelson AG, Cornwell A. Acute muscle stretching inhibits maximal strength performance. Research Quarterly in Exercise and Sport 69(4):411-415, 1998.

15. Kubo K, Kanehisa H, Fukunaga T. Effects of resistance and stretching training programmes on the viscoelastic properties of human tendon structures in vivo. Journal of Physiology 538(Pt 1):219-226, 2002.

16. Manoel ME, Harris-Love MO, Danoff JV, Miller TA. Acute effects of static, dynamic, and proprioceptive neuromuscular facilitation stretching on muscle power in women. Journal of Strength & Conditioning Research 22(5):1528-1534, 2008.

17. McMillian DJ, Moore JH, Hatler BS, Taylor DC. Dynamic vs. Static-stretching warm up: The effect on power and agility performance. Journal of Strength & Conditioning Research 20(3):492-499, 2006.

18. Mitchell MF. Stretching the content of your warm-up. Journal of Physical Education, Recreation & Dance 67(1996):24-28, 1996.

19. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. International Journal of Exercise Science 12(1):1-8, 2019.

20. Neiva HP, Marques MC, Barbosa TM, Izquierdo M, Marinho DA. Warm-up and performance in competitive swimming. Sports Medicine 44(3):319-330, 2014.

21. Nelson AG, Kokkonen J, Arnall DA. Acute muscle stretching inhibits muscle strength endurance performance. Journal of Strength & Conditioning Research 19(2):338-343, 2005.

22. Olympics T. Tokyo 2020 swimming olympics schedule & results. In: 2021.

23. Power K, Behm D, Cahill F, Carroll M, Young W. An acute bout of static stretching: Effects on force and jumping performance. Medince and Science in Sports and Exercise 36(8):1389-1396, 2004.

24. Ryan ED, Everett KL, Smith DB, Pollner C, Thompson BJ, Sobolewski EJ, Fiddler RE. Acute effects of different volumes of dynamic stretching on vertical jump performance, flexibility and muscular endurance. Clinical Physiology and Functional Imaging 34(6):485-492, 2014.

25. Segal SS, Faulkner JA, White TP. Skeletal muscle fatigue in vitro is temperature dependent. Journal of Applied Physiology 61(2):660-665, 1986.

26. Sharp RL, Hackney AC, Cain SM, Ness RJ. The effect of shaving body hair on the physiological cost of freestyle swimming. Journal of Swimming Research 4(1):9-13, 1988.

27. Shellock FG, Prentice WE. Warming-up and stretching for improved physical performance and prevention of sports-related injuries. Sports Medicine 2(4):267-278, 1985.

28. Statista. USA swimming membership 2000-2019. In: 2021.

29. Wright V. Stiffness: A review of its measurement and physiological importance. Physiotherapy 59(4):107-111, 1973.

30. Young W, Behm D. Should static stretching be used during a warm-up for strength and power activities? Strength and Conditioning Journal 24:33-37, 2002.

31. Young WB. The use of static stretching in warm-up for training and competition. International Journal of Sports, Physiology, and Performance 2(2):212-216, 2007.

TOPICS IN EXERCISE SCIENCE AND KINESIOLOGY

Expedited Article

Stretching After an In-Water Warm-Up Does Not Acutely Improve Sprint Freestyle Swim Performance in DIII Collegiate Swimmers

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Our study was designed to determine if static stretching (e.g., pulling arm across chest for a shoulder stretch) or dynamic movements (e.g., slow arm circles to engage shoulders), when added to an in-water swimming warm-up, resulted in a change in freestyle swimming performance. Fifteen Division III collegiate swimmers completed three sessions on different days, performing either an in-water warm-up alone, an in-water warm-up and static stretching, or an in-water warm-up and dynamic movements before completing three, 100-yard freestyle sprint trials with ~3 minutes rest between trials.

Our results (Table 1 below) demonstrate no improvement in swim performance with static stretching or dynamic movements. In fact, the fastest peak and average times were seen with the in-water warm-up only trials. These trials were ~0.7-0.8 seconds faster than the dynamic movement trials and, while not statistically significant, trended toward being faster than the static stretching trials (~0.4-0.5 seconds).

While our results do not directly apply to different swim distances, stroke types, or populations of swimmers, they are in agreement with other swim studies that have been performed. Collectively these studies demonstrate that an activity-specific warm-up appears to be the single best method of preparaion for a hard swim workout or race. Adding dynamic movements or static stretching to an in-water warm-up does not seem to improve sprint, freestyle swim performance and may actually hinder it.

Table 1. Times for 100-yard sprints across the different conditions.

	In-water warm-up	**In-water warm-up + dynamic movements**	**In-water warm-up + static stretching**
Peak performance	61.84 (4.53)	62.64 (4.66)	62.39 (4.53)
Average performance	62.57 (4.56)	63.34 (4.60)	62.99 (4.22)

Times are shown in seconds, as mean (standard deviation).