EFFECT OF DIFFERENT WARM-UPS AND UPPER-BODY VIBRATION ON PERFORMANCE IN MASTERS SWIMMERS

by

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A THESIS

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ABSTRACT

The purpose of the study was to evaluate the effects of no, short, or regular warm-up and Upper-Body Vibration (UBV) only or UBV+ short warm-up on swimming performance in Masters Swimmers. Six females and four males, aged 24-50, healthy master swimmers volunteered to participate in the study. Participants completed all assigned warm-ups (no, short, regular, UBV-only, or UBV + short) in counterbalanced order, rested for three minutes and completed a 50-yard (45.7 m) freestyle maximal performance time trial. Rating of perceived exertion (RPE) and heart rate (HR) were measured post warm-up and post 50-yd time trial. No significant difference \((p = 0.987)\) was found among no, short or regular warm-up regarding 50-yd freestyle time (29.0 ± 3.7, 29.0 ± 3.6, and 29.1 ± 3.4 s, respectively). No significant difference \((p = 0.563)\) was found among regular, UBV-only or UBV + short warm-ups regarding 50-yd freestyle time (29.1 ± 3.6, 28.9 ± 3.4, and 29.1 ± 3.6 s, respectively). RPE after no warm up (6 ± 0) was significantly lower compared to after short (13 ± 2, \(p < 0.001)\) or regular warm-up (12 ± 2, \(p < 0.001)\). RPE after regular warm-up was higher (12 ± 2) compared to UBV-only warm-up (9 ± 2), approaching statistical significance \((p = 0.059)\). RPE post 50-yd for no, short or regular warm-up and after regular, UBV-only or UBV + short were not significantly different \((p =0.76, p = 0.216)\). HR after no, short or regular warm-up before 50-yards was not significantly different \((p = 0.062)\); however, a significantly higher \((p = 0.023)\) HR was observed after regular warm-up (88 ± 15 b/min) compared to UBV + short (75 ± 9 b/min). HR post 50-yd after regular warm-up (148 ± 15 b/min) was significantly higher compared to no (136 ±20 b/min) \(p = 0.001, \) UBV-only (139 ± 12 b/min) \(p = 0.005\) and UBV + short (138 ± 14 b/min) \(p = 0.013, \) but not short (142 ±
17 b/min) warm-up ($p = 0.077$). In conclusion, Master Swimmers may perform the same or better with no or short and UBV-only or UBV + short, compared to regular warm-up.
DEDICATION

I dedicate this thesis to my parents Tatjana Nepocatych and Aleksandr Nepocatych who have been a great example as parents to me and my brother Dmitrij Nepocatych and his family that supported me. Also, I would like to dedicate this thesis to Madeline Haft for being such an inspiration and Brown family for a great opportunity.
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I would like to express my greatest appreciation to Dr. Phillip A Bishop for guiding me to the successful end of thesis journey of research and writing, for his advice and encouragement throughout, and to a new beginning. The quality of this study was greatly enhanced by the direction and assistance of Dr. Bishop and fellow students Gytis Balilionis and Carrie Ellis that contributed to the development of this study.

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<td>ANOVA</td>
<td>analysis of variance</td>
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<tr>
<td>cm</td>
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<td>EMG</td>
<td>Electromyography</td>
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<td>LSD</td>
<td>least significant difference</td>
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<td>N</td>
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<td>p</td>
<td>probability associated with the occurrence under the null hypothesis of a value as extreme as or more extreme than the observed value</td>
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<td>PAR-Q</td>
<td>Physical Activity Readiness Questionnaire</td>
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<td>SD</td>
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<td>SPSS</td>
<td>Statistical Package for the Social Sciences</td>
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<td>UBV</td>
<td>upper-body vibration</td>
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* significant difference ($p < 0.05$)
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INTRODUCTION

In order to optimize swimming performance in Master Athletes, training methods and warm-up techniques should be considered. There is little research available on Master Swimmers and optimal warm-up techniques.

Swimming is a competitive event where swimmers usually perform in the prelims early in the morning and final heats later in the afternoon. Therefore, swimming is a demanding sport requiring extreme muscle strength, power, and endurance. Swimming different events ranging from 50 to 1500 meters requires different training and warm-up techniques. Typically, warm-up is used before the race to optimize athletic performance by increasing body’s temperature, flexibility and stimulating greater metabolic and cardiovascular changes (2, 3, 13, 19). However, warm-up should not cause fatigue or deplete energy stores (13).

Two types of warm-up are used in sports: passive (increasing body’s temperature by external means) and active (increasing body’s temperature by exercise) (2). Active warm-up is widely used across sports before short-distance and long-distance performances. Short-distance athletic performance is dependent on the availability and breakdown of high-energy phosphate stores. If warm-up is intense enough to deplete high-energy stores it may impair athletic performance (2). Therefore, duration, intensity, and recovery period after warm-up play an important role in athletic performance (2, 3).
A standard warm-up distance for the majority of swimmers may consist of anywhere between 1500 and 2200 meters for short- and long-distance events (1, 23). A typical warm-up for Master Athletes is anywhere between 600-1500 meters at self chosen moderate pace (15). The results are inconclusive regarding whether active warm-up improves or impairs swimming performance (3). In a review article, Bishop (2003b) concluded that three to five minutes of moderate-intensity warm-up significantly improved short-distance performance; whereas, low intensity warm-up had no effect on short-distance performance. Bobo (1999) found no significant difference among three different types of warm-up (no, related-swimming, and unrelated dry-land warm-up) on mean or best 100-yard freestyle performance. Romney and Nethery (1993) found that 100-yard swimming performance was significantly improved after swimming a 15 minute warm-up compared to no warm-up. However, Mitchell and Huston (1992) found no significant differences in 200-yard swimming performance after no, short, and regular warm-ups. Therefore, the effectiveness of active warm-up on swimming performance remains uncertain. Furthermore, warm-up procedures have to be evaluated based on duration, intensity and type.

Whole body vibration (WBV) is an emerging training method. It is hypothesized that mechanical stimulus to the muscle can be an effective way of improving muscle strength and power (7). Research results have been equivocal with the majority of studies focusing on the effects of WBV on strength training (14), sprint performance (12), muscle activity (6), vertical jump (9), flexibility (10), and agility of the lower body (9). A proposed mechanism for WBV is increased gravitational load and acceleration forces causing the muscle to lengthen and
subconsciously contract (7). Therefore, more muscle fibers are used and a more forceful contraction may be produced (7).

Only two studies have been completed using upper-body vibration (UBV) (as opposed to whole body vibration). Bosco et al. (1999) and Cochrane et al. (2007) examined the acute effects of UBV using different application methods. Bosco et al. (1999) found a significant increase in average EMG activity during UBV and a significant increase in mechanical power during max dynamic elbow flexion. However, Cochrane et al. (2007) found no significant treatment effect of for UBV in medicine ball throw and hand grip strength. Based on these findings, it’s difficult to determine whether UBV affects performance.

Muscle strength, power and endurance are very important factors in sprint and endurance trained swimmers. Swimmers move their body through the water relying mostly on muscle strength and muscle endurance (20). UBV might affect swimming performance due to its ability to activate multiple motor units with minimal fatigue. Therefore, with regard to extant controversies, this study focused on different types of warm-ups and upper-body vibration and their effect on swimming performance in Masters Swimmers. We hypothesized that short warm-up or no warm-up would be better or provide equal benefits as a regular warm-up. In addition, UBV and short warm-up or UBV-only would provide better or equal benefits as regular warm-up on swimming performance. The purpose of this study was to evaluate the effects of three different types of warm-ups in the first part of the study (no warm-up, short warm-up, and regular warm-up) and three in a second part of the study UBV (regular warm-up, UBV + short warm-up, and UBV-only) on swimming performance in Masters Swimmers.
METHODS

Participants

The participants consisted of four male and six female healthy Masters Swimmers between 24 and 50 years of age. To participate, all participants had to have practiced at least three times per week for at least six months in order to ensure that participants were trained swimmers. Prior to the study, participants had to sign an informed consent form and complete the Physical Activity Readiness Questionnaire (PAR-Q), and current health status and training status questionnaires. In addition, participants were asked not to participate in physical activity and avoid alcohol at least 24 hours prior to each test session.

The informed consent form was prepared according to the guidelines of local Institutional Review Board and approved prior to the study. Prior to the study, the purpose of the study and performance trials were explained, different types of warm-up were introduced, and health risks and benefits were explained. Only trained athletes participated and none of the requirements of this study, save the brief exposure to vibration, exceeded their normal efforts in swim training. There are no previous studies that reported any serious adverse effects of vibration (8, 18).

Participants were excluded from the study if they met any of the following criteria: participant was younger than 24 or older than 50 years; recently had a shoulder injury; screening forms indicated any previous cardiovascular, respiratory or other major chronic diseases;
participant had any type of surgery or injury that may have increased their risk of exercise participation; or participant had not practiced at least three times per week for at least six months.

Descriptive data such as age, weight, and height were collected. The participants were wearing only a swimsuit during the weighing procedure. Participants’ height was self reported in inches and converted to centimeters. Body composition was assessed using a skinfold caliper (LANGE, Beta Technology Incorporated, Cambridge, Maryland). Skin folds were measured at the thigh, chest and abdomen area for male and at the superiliac, triceps and thigh for female (17). Three measures were taken at each site and the average of the three was recorded. Sum of skinfolds was calculated by adding the averages of the three measurements. Body fat was estimated using sum of skin folds and age (17). Years of swimming experience, current training status, preferred stroke and distance, best 50-yard time, and prior upper-body injury were assessed using a training status questionnaire. Also, participants were verbally introduced to the five (regular warm-up was used in both parts of the study) different warm-up types and testing procedures.

Protocol

Participants completed five performance trials in counterbalanced order, separated by at least 48 hours between each performance trial. As mentioned earlier, regular warm-up was used for both parts of the study. Testing occurred between early morning and noon. Each participant completed a 50-yard maximal performance (time) trial after each warm-up.
In sessions I-V participants completed the following schedule:

*No warm-up* – the participant rested for five minutes. After resting for five minutes, participant completed a 50-yd maximal-performance time trial.

*Short warm-up* – the participant completed a 100 yard freestyle swim. Fifty yards was completed at 40% of their maximal effort and another 50 yards at 90% of their maximal effort.

*Regular warm-up* – the participant completed their own swimming competition warm-up, which was no less than 500 yards, with no limits on distance and included at least two 25-yd sprints at 90% of their maximal effort.

*UBV + Short warm-up* – the participant completed a 100-yard freestyle swim. Fifty yards was completed at 40% of their maximal effort and another fifty yards at 90% of their maximal effort. After the short warm-up, participant performed UBV for five sets one minute each with one minute and 15 seconds rest between sets.

*UBV-only warm-up* – the participant performed UBV for five sets of one minute each with one minute and 15 seconds rest in between sets.

The participant rested after short, regular, UBV-only and UBV + short warm-up for three minutes and then completed the 50-yd maximal performance time trial. During the three minutes
of rest, participants were allowed to put cap and goggles on. Participants were allowed to stand, sit, walk and talk as they would during the competition before the race.

_Vibration procedure_

Vibration treatments were completed on a swim bench (Vasa Trainer Pro, Vermont) with an attached UBV device (Figure 1). The swim bench was locked at incline position. Participants kept both hands on the UBV device (American Prototype build based on Russian model, USA Swimming, Colorado Springs, CO) and applied pressure. Participants were required to maintain proper technique by keeping elbows high and aligned with the shoulder line. Each participant was exposed to five one-minute vibration sets with one minute and fifteen seconds of rest in between sets. This was similar to the protocol of UBV mechanical vibration used previously by Bosco et al (1999) during arm flexion exercise at vibration frequency of 30 Hz. Duration of the total vibration treatment in the present study was five minutes. Vibration frequency was fixed at 22 Hz.

_Performance Evaluation_

_Maximal performance time trial_. Participants completed 50-yards of freestyle swimming. The fifty yards freestyle requires a flip turn due to the short-course (25-yd) pool. Master swimmers are trained and adept to flip turns with competitions held in short course pool such as 2009 Short Course National Championship (21). The 50-yd time trial was used as opposed to the longer event which might have diminished the effect of the warm-up due to multiple laps and flip turns. Two people with identical digital stop watches were used to time the performance trial and the average of the two trials was recorded to give a mean performance time. Swim times were
recorded to the nearest 0.1 second. To start a time trial the following verbal command was used “Take your Mark” and “Go” instead of an electronic beep.

*Warm-up session and 50-yd freestyle time trial RPE.* After warm-up and performance time trial, participants were asked to rate their perceived exertion (RPE) on a Borg’s 15 point scale (6-20) (5). Each participant was visually and verbally reminded of the Borg’s 15 point scale after the warm-up and time trial.

*Fifty-yd freestyle time trial HR.* Before and after each performance time trial participants were asked to obtain heart rate. Heart rate was measured by manual palpation method at the wrist or neck for 15 seconds. Participants were accustomed to doing this in normal swim practices.

*Stroke count.* During the 50-yd freestyle performance time trial, stroke cycles were counted and recorder. One cycle was equal to two strokes. The cycle started when the first arm of a participant entered the water and ended when it recovered.

**Statistical Analyses**

Differences among the warm-ups for the two hypotheses (Hypothesis 1: no significant difference among: no warm-up, short warm-up and regular warm-up and Hypothesis 2: no significant difference among: regular warm-up, UBV-only warm-up and UBV + short warm-up) on 50-yd (45.7 m) freestyle time, RPE post warm-up, RPE post time trial, HR before and after the time trial and stroke count were analyzed using separate repeated measures ANOVAs (SSPS Version 16.0). If a main effect was detected, LSD post hoc multiple comparisons were used in
order to determine the difference among the three different types of warm-ups for each analysis. An alpha value was set at 0.05. Individual data, as a number of individuals performed their best time after given warm-up was reported as percentage of the total group.
RESULTS

Participants reported being healthy and training at least three days a week. Two of the male participants were triathletes. A majority of participants reported having at least three years of experience. Participants’ age, weight, height, percent body fat, years of experience, preferred stroke and best 50-yd time are presented in Table 1. The regular warm-up swim before 50-yd performance time trial was 800 ± 276 yd for females and 500 ± 0 yd for males.

Hypothesis 1. No significant difference ($p = 0.987$) was found between no, short and regular warm-ups for 50-yd (45.7 m) freestyle times of 29.0 ± 3.7, 29.0 ± 3.6, and 29.1 ± 3.4s, respectively. Group mean and individual data for 50-yd freestyle times are presented in Figure 2. Individual data indicate that 50% (N = 5) of the swimmers swam faster with no warm-up, 20% (N = 2) of the swimmers swam faster with short warm-up, and 30% (N = 3) of the swimmers recorded their best time with their regular warm-up.

RPE post-warm-up was significantly different ($p < 0.001$) among the three warm-ups. RPE after no warm-up (6 ± 0, i.e. resting) was significantly lower than after short warm-up 13 ± 2 ($p < 0.001$) and regular warm-up 12 ± 2 ($p < 0.001$). However, no significant difference was found for the after time trial RPE ($p = 0.76$) among no warm-up (16 ± 2), short warm-up (17 ± 2), or regular warm-up (17 ± 2) (Figure 3).
HR after no warm-up of (76 ± 9 b/min), short warm-up (84 ± 23 b/min) and regular warm-up (88 ± 15 b/min) approached but did not reach statistical significance \((p = 0.062)\) (Figure 4). A significant difference was found \((p = 0.002)\) in HR after the time trial between no, short and regular warm-ups. HR after no warm-up (136 ± 20 b/min) was lower \((p = 0.001)\) compared to regular warm-up (148±15 b/min) and approached but did not reach statistical significance \((p = 0.052)\) compared to short warm-up (142 ± 17 b/min) (Figure 4). No significant \((p = 0.077)\) difference in HR was observed between short and regular warm-ups. Stroke count was not significantly different \((p = 0.322)\) among the three warm-ups (no 36 ± 6, short 35 ± 6, and regular 35 ± 7 (Figure 5).

\textit{Hypothesis 2}. No significant difference \((p = 0.563)\) was found among regular, UBV-only and UBV + short warm-ups for 50-yd freestyle times of 29.1 ± 3.4, 28.9 ± 3.4, and 29.1 ± 3.6 s, respectively. Group mean and individual data of 50-yd freestyle time are presented in Figure 6. Individual data indicated that 40\% (N = 4) of the swimmers swam their fastest with UBV-only and 20\% (N = 2) with UBV + short warm-ups compared to 40\% (N = 4) of the swimmers who swam their fastest with regular warm-up.

A significant difference \((p = 0.043)\) was found among post-warm-up RPEs. The difference in RPE after regular warm-up (12 ± 2) and UBV-only warm-up (9 ± 2) approached, but did not reach, statistical significance \(p = 0.059\). RPE after UBV+ short warm-up (10 ± 2) did not differ significantly from regular and UBV-only warm-ups \((p = 0.160\) and \(p = 0.089\) respectively). No significant difference \((p = 0.216)\) was found between post swim time trial RPE
after regular warm-up (17 ± 2), UBV-only (16 ± 1) and UBV + short warm-up (16 ± 2) (Figure 7).

A significant difference was found between HRs before ($p = 0.023$) the time trial. HR was significantly ($p = 0.015$) higher after regular warm-up (88 ± 15 b/min) compared to UBV + short warm-up (75 ± 9 b/min). HR after UBV-only (80 ± 14) did not differ significantly from regular and UBV + short warm-ups ($p = 0.121$ and $p = 0.212$ respectively) (Figure 8). In addition, HR after the time trial was significantly ($p = 0.009$) different among the three warm-ups. HR after the time trial was found to be significantly higher after regular warm-up (148 ± 15 b/min) compared to after the UBV-only warm-up (139 ± 12 b/min) and the UBV+ short warm-up (138 ± 14 b/min) ($p = 0.005$ and $p = 0.013$ respectively) (Figure 8). Stroke count was not significantly different ($p = 0.62$) among regular (35 ± 7), UBV-only (36 ± 6) and UBV + short (35 ± 5) warm-ups (Figure 9).
DISCUSSION

Controversy exists in the literature regarding how long and what mode of warm-up swimmers need. Therefore, the purpose of the present study was to examine the effect of different types of warm-ups (no-, short-, regular, and regular, UBV + short, UBV-only) on 50-yd freestyle times in Master Swimmers. It was hypothesized that short warm-up or no warm-up would be better or would provide the same benefits as regular warm-up. In addition, UBV and short warm-up or UBV-only warm-up would be better or would provide the same benefits as regular warm-up on swimming performance. These hypotheses were both supported by the group mean data.

The main physiological changes occurring during active and passive warm-ups are increased core and muscle temperature in order to increase vasodilation within the muscles to allow for more blood and oxygen to be delivered to the active tissue (2, 13). In addition, active warm-up hypothetically prepares the cardiovascular and respiratory systems enhancing energy availability and its production (3).

To the best of our knowledge this is the first published study to date evaluating the effects of upper-body vibration on swimming performance. Limited evidence exists to support whether no warm-up or swimming high- or low- volume warm-up and high- or low- intensity warm-up improves or worsens the performance. Usually intensity, duration, recovery periods, mode and
choice of continuous or intermittent type of warm-up depend on the individual experience of the athlete and coach (2, 3).

Swimming performance may be optimized by performing either no warm-up, dry-land warm-up or UBV-only warm-up where pre-race warm-up pools are unavailable. The results of the current study indicate that there was no significant mean difference found among the three types of warm-up (regular, UBV-only or UBV+ short). Although group means did not reach statistical significance, group means tended towards being slower for regular warm-up (29.1 ± 3.4 seconds) compared to UBV-only warm-up (28.9 ± 3.4 seconds). If accurately measured, a tenth of a second can separate the winner from the second place, mean differences this small could be of practical significance.

Even though UBV-only and UBV + short warm-up did not differ significantly from regular warm-up, vibration has previously been suggested to improve performance and EMG activity of the involved muscles (6). The lack of improvement during UBV could be due to the inability to prepare race-specific muscles as regular swimming warm-up would do. Also, UBV warm-up may not have been intense enough or long enough to prepare for optimum performance compared to a regular swimming warm-up. After completing each warm-up and the 50-yd time trial, participants rated RPE. RPE after regular, UBV-only or UBV+ short warm-up sessions approached but did not reach statistical significance. RPE after regular warm-up (12 ± 2) was higher than after UBV-only warm-up (9 ± 2) or UBV + short warm-up (10 ± 2). Participants did not feel as fatigued after UBV-only or UBV + short warm-up and both were perceived as less demanding warm-ups compared to regular warm-up. RPE after the 50-yd time trial did not differ
significantly among the three warm-ups. In addition, heart rates after warm-up and 50-yd time trial after regular warm-up were higher compared to UBV-only and UBV + short warm-up. Thus, regular warm-up was more demanding on the cardiovascular system compared to UBV-only and UBV + short warm-ups.

There was no way of measuring how much pressure each participant was applying to the UBV device; therefore, UBV could have had a varied effect on the experienced vibration stimulus and intensity of the warm-up. Participants were trained swimmers; however, they were not accustomed to the vibration stimulus. It is possible that UBV warm-up would have a greater ergogenic aid if swimmers were adapted to a UBV routine. If vibration stimulus was performed more often and at a higher intensity, participants may have gained greater benefits.

With no previous research available on UBV and swimming performance there was a need to examine not only group mean data, but also individual results. As illustrated in Figure 6, 40% of the swimmers swam faster with regular warm-up compared to 40% with UBV-only and 20% with UBV + short warm-up. However, one must note that the present study used a sample size of 10 participants. How stable and repeatable swimming performance will remain after each warm-up needs to be further investigated. Though, it may be suggested that half of the participants gained benefits from UBV even though it did not attain group mean statistical significance. If improved results proved stable for a particular swimmer, it could be recommended to use UBV as a warm-up routine or as an addition to swimming a short warm-up before the race.
In addition, the present study evaluated the effect of no, short and regular warm-up on 50-yd freestyle performance. No significant differences were observed among the three warm-up types. The findings of the current study support previous research by Bobo (1999) who found no significant difference among three different types of warm-up (no-, a related swimming warm-up and an unrelated dry-land warm-up) on mean or best 100-yard freestyle performance. Mitchell and Huston (1992) reported no difference after no-, high- or low- intensity warm-up on standardized and tethered 200-yard freestyle time trials. However, Romney and Nethery (1993) reported a slower 100-yard freestyle time performance after no warm-up compared to a swimming warm-up (-0.75s). Moreover, they observed a trend towards slower times after no warm-up was observed compared to the dry-land warm-up (-0.65s); however, it did not reach statistical significance. Therefore, it was suggested that swimming warm-up elevated body’s temperature and caused other warm-up associated physiological changes, provided environmental familiarization, also, swimming specific skills were practiced.

Performance can be influenced by neuromuscular and environmental adaptations. Neuromuscular adaptations are influenced by specific practice skills (19) and may influence performance. However, in the present study, participants were actively training and adept to flip turns required during 50 yards freestyle. Participants trained in the testing facility regularly and were familiar with the pool and its environment. Not all of the participants competed in freestyle swimming but most of the training volume derived from freestyle swimming.

Previous studies by Mitchell et al (1992) and Bobo (1999) found no significant difference in swimming performance group means after different warm-ups. Moreover, individual data
were not reported to compare warm-up effects on individual performance. It is important to examine individual data because coaches work with individuals and not group means. Individual data illustrated in Figure 2 indicated that 50% of participants swam their fastest with no warm-up and 20% with short warm-up compared to 30% of participants with regular warm-up. Stability and repeatability of swimming performance after no-, short- and regular warm-up needs to be determined. However, the greatest advantage of no- or short warm-up before the race could be that it would limit fatigue and depletion of the high-energy stores. This may account for better sprint performance where most of the energy is derived from PCr (phosphocreatine) and muscle glycogen. This might be especially beneficial when swimmers are competing in multiple events and heats and finals in the same day.

Perception of the competitive environment varies with each individual and, a multitude of psychological and physiological responses may occur (2, 13, 16). Participants performing better with regular warm-up may have a fundamental belief that regular warm-up leads to swimming faster, preventing injury or increasing ability to perform at maximum speed. Intensity and duration of regular warm-up varied among participants since participants swam their own preferred meet warm-up with two 25-yards sprints. Longer warm-ups may have decreased energy stores and availability (3), and increased metabolic by-product concentrations (16). Previously, higher lactate concentrations were observed after high-intensity warm-up compared to no warm-up (16). Insufficient rest after warm-up of only three minutes could have influenced swimming performance where in some cases pre-race warm-up occurs an hour or more before the race (19). Also, the small sample size and large age and performance variability among participants influenced the ability to detect significant differences. The lack of improvement after
any of the warm-ups might have been influenced by motivation. Participants competed against themselves and the clock, without other competitors which might have decreased their effort. (19).

Lower RPE was found after no warm-up compared to the short or regular warm-ups; however, no difference was found in RPE after the swim time trial. This was expected since RPE is sensitive to intensity and volume of work performed. After no warm-up, participants had lower heart rates compared to regular and short warm-ups. However, the accuracy of the heart rate measured by manual palpation needs to be considered. Lower mean heart rate was previously reported after no warm-up versus low and high intensity warm-up by Mitchell and Huston (1992). Participants rated warm-ups as being same intensity; however, it may be hypothesized that higher demand on a cardiovascular system occurred after regular warm-up. It has been suggested that long and intense active warm-up may increase body’s temperature (3). An increased tissue temperature causes increased demands of the cardiovascular system (22). Therefore, it has been hypothesized that during exercise increased temperature may produce cardiovascular system adaptations by maintaining an elevated heart rate in order to cool tissues and provide blood and oxygen to the active muscles (22). This was supported by a previous study by Mitchell and Huston (1993) where elevation in VO$_2$max was observed after high-intensity warm-up suggesting increased cardiac output during intense exercise. Lower heart rate observed after short warm-up, could be due to insufficient intensity and duration to elevate body’s temperature, therefore, causing lower heart rate compared to the regular warm-up.
Stroke count was not significantly different after no, short and regular warm-ups. In addition, no differences were found among regular, UBV-only and UBV+ short warm-ups. An observed reduction in number of strokes after UBV-only or UBV + short warm-ups was hypothesized due to proposed mechanism of increased neuromuscular stimulus, increased muscle activation and generation of more forceful contraction (6) therefore, increasing the length of the stroke. This was not seen in the present study. Absence of improvement could be due to limited adaptation to the vibration load and stimulus. Vibration load may have been insufficient to generate any physiological changes associated with vibration leaving optimal duration and frequency yet to be determined.
CONCLUSION

In conclusion, swimming performance did not differ when using no warm-up or short warm-up compared to regular warm-up. No- and short- warm-up were perceived as less strenuous compared to regular warm-up. Elevated heart rate after regular warm-up indicated higher demand on a cardiovascular system. In addition, no difference in swimming performance was observed after regular, UBV-only and UBV + short warm-ups. Lack of improvements after UBV-only and UBV + short warm-ups may have been due insufficient adaptation to vibration stimulus and duration of vibration load.
Because of individual variability, coaches should focus on the individual swimmer and not the group response in order to maximize training. Therefore, individual data must be considered as valuable information. If a swimmer consistently performs better with no- or short-warm-up, the athlete and coach should take advantage of this. Neuromuscular rehearsal of warm-up is considered an important aspect in optimizing any performance; this is not present in no-WU but is in short- and regular- swimming or dryland warm-up. Coaches should experiment during the athletes pre- and post-season to determine the best possible warm-up length, intensity and mode in order to improve swimming performance. The results of the present study may be applied to the sprint events swimming athletes; however, for longer events other warm-up routines may be needed. Nonetheless, some individuals may need longer warm-ups than others to achieve optimal conditions in order to perform their best. Adaptations to warm-up routines, optimal rest intervals post warm-up, intensity and mode should be considered. UBV is a new research area that needs to be further investigated. Optimal duration of vibration loading, frequency and rest period needs to be determined. UBV warm-up may gain benefits if rehearsed.
REFERENCES


Table 1. Physical Characteristics of Participants (N = 10)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Female N = 6 Means ± SD</th>
<th>Male N = 4 Means ± SD</th>
</tr>
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<tbody>
<tr>
<td>Age (y)</td>
<td>34 ± 8</td>
<td>37 ± 10</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>66 ± 6</td>
<td>72 ± 7</td>
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<td>Height (cm)</td>
<td>172 ± 4</td>
<td>177 ± 2</td>
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<tr>
<td>% body fat</td>
<td>28 ± 7</td>
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<td>Swimming experience (yrs)</td>
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<td>15 ± 15</td>
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<tr>
<td>Best 50-yard time (sec)</td>
<td>26.3 ± 3.3</td>
<td>29.5 ± 7.0</td>
</tr>
<tr>
<td>Preferred Stroke</td>
<td>Free/Back</td>
<td>Free/Fly</td>
</tr>
</tbody>
</table>
FIGURES

Figure 1. Upper Body Vibration Device and Vasa Swim Bench
Figure 2. Individual results and group mean for 50-yd freestyle time trail after no-, short- and regular- warm-ups (N = 10)
Figure 3. POST RPE following no-, short- and regular- warm-ups and POST-50 RPE (N = 10)

* RPE after no-warm-up was lower compared to after short- and regular- warm-ups ($p < 0.05$).
Figure 4. HR before and after 50-yd freestyle time trial following no-, short- and regular- warm-ups (N = 10)

* HR after 50-yd freestyle time trial was lower after no warm-up condition compared to regular warm-up condition ($p < 0.05$).
Figure 5. Stroke count during 50-yd freestyle time trial after no-, short- and regular- warm-ups (N = 10)
Figure 6. Individual results and group mean for 50-yd freestyle time trail after regular-, UBV-only and UBV + short warm-ups (N = 10)
Figure 7. POST RPE following Regular-, UBV-only and UBV+ short warm-ups and POST-50 RPE (N = 10)
Figure 8. HR before and after 50-yd freestyle time trial following regular-, UBV-only and UBV + short warm-ups (N = 10)

* HR before 50-yd freestyle time trial was lower after UBV + short warm-up condition compared to after regular warm-up condition (p < 0.05).
* HR after 50-yd freestyle time trial was lower for UBV + short warm-up and UBV-only condition compared to regular warm-up (p < 0.05).
Figure 9. Stroke count during 50-yd freestyle time trial after regular-, UBV-only and UBV + short warm-ups (N = 10)