Effects of Swim Strokes in Labor-wear With and Without a Personal Flotation Device

John Amtmann, Whitewater Rescue Institute, Lolo, Montana and Montana Tech, Safety Health, Industrial Hygiene Department, Butte, Montana 59701

Kelly Amtmann, Montana Tech, Nursing Department, Butte, Montana 59701

Cody Harris, Whitewater Rescue Institute, Lolo, Montana 59847

Seth Schutte, Montana Tech, Safety, Health and Industrial Hygiene Department, Butte, Montana 59701

William Spath, Montana Tech, Safety, Health & Industrial Hygiene Department, Butte, Montana 59701

Charles Todd, Montana Tech, Department of Mathematical Sciences, Butte, Montana 59701

Abstract

We determined how three different swim strokes were affected by standard labor-wear with and without use of a personal flotation device (PFD). The two main research questions included (1) what effects would standard labor-wear have on the American crawl, elementary back stroke and breast stroke with and without a PFD for 11.4 m (12.5 yds). The sub questions included: (2) Will the addition of the PFD improve swim times? We addressed these questions with six hypotheses. Statistical analysis showed statistically significant *P*-values for the American crawl (no PFD 23.29 sec, PFD 18.29 sec, $P = 0.0010$) and back stroke (no PFD 36.96 sec, PFD 31.00 sec, $P = 0.0223$); the strokes showed improved swim times with the PFD. We detected no statistical evidence ($P = 0.2086$) for the mean swim time (22.61 sec) for the breast stroke with PFD and the mean swim time (23.00 sec) for breast stroke without a PFD. Swim time between swimmers with and without a PFD differed. The mean swim time for all swimmers with a PFD (24.17sec) was faster than the mean swim time for all swimmers without a PFD (27.75 sec, $P = 0.0153$). The mean swim time for swimmers using the elementary back stroke (33.98 sec) was slower than the mean swim time for swimmers using the crawl stroke (21.10 sec, $P < 0.0001$) and the mean swim time for swimmers using the breast stroke (22.81 sec). We detected no difference between the mean swim time for swimmers using the crawl stroke and the mean swim time for swimmers using the breast stroke. We also detected no evidence ($P = 0.164$) of a stroke X flotation interaction effect.

Keywords: swim stokes, labor-wear, swim times, personal flotation device, life vest

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Introduction

We examined the effects of different swim strokes while wearing standard work clothing, with and without a personal flotation device, on subjects' abilities to swim 11.4 m (12.5 yds) relevant to work performed on or near water. For example, on 2 May 2003, a laborer was working near a pond in Oregon. The pond was surrounded by an angled embankment where the laborer was placing rocks at strategic locations on the inclined bank to prevent erosion. The laborer fell down the embankment and into the pond. By the time he was rescued from the water, first responders were unable to resuscitate him. It took them 47 min to locate and remove the body before resuscitation efforts began (NIOSH 2003).

In March 2011, a train derailment along the Kootenai River in Northwest Montana required railway workers to be transported to the derailment site via jet boat and to work on an inclined embankment along the river. The ensuing clean-up effort lasted 4 mos and involved > 1000 people. Many of the laborers were transported on jet-boats to islands and worked in close proximity to the flooding river. During this time, the air temperature fluctuated between -1-12 ˚C (30-54 ˚F), the Kootenai River was flowing at about 566.34 m^3/ sec (20,000 ft^3/ sec) and the temperature of the water was about 3.8 ˚C (39 ˚F) (U.S. Geological Survey 2011).

A common question of the laborers during transport was, “If we fall into the drink [while working], how long would we be able to stay up before you guys are able to rescue us?” The average worker transported to the worksite was wearing standard workwear: a hard hat with a liner, a heavy Carharrt® canvas jacket with insulation under the jacket, Carharrt® canvas bib coveralls and heavy leather work-boots with steel-toe protection. Amtmann et al. (2012) tested the hypothesis that occupational clothing would impair performance during swimming and treading water.

Further, Amtmann et al. (2012) provided evidence that standard laborwear had adverse effects on 11.4-m swim time, water treading time and rate of perceived exertion (RPE) on the Borg (1998) scale during water treading. The mean swim time more than doubled when the subjects wore standard labor-wear and their average rate of perceived exertion increased from 11.6 in standard swimwear to 17.1 in standard labor-wear. Because the trials excluded the use of a personal flotation device (PFD), the authors’ recommendations for future research included comparing the effectiveness of different strokes with and without a PFD (Amtmann et al. 2012).

The Occupational Safety and Health Administration requires use of personal protective equipment and PFDs when individuals are working on, over or near water when a drowning hazard exists (U.S. Department of Labor 1926.106(a)). The purpose of the current research was to determine how three different strokes were affected by standard labor-wear with and without use of PFDs.

The two main research questions included (1) what effects would standard labor-wear have on the American crawl, elementary back stroke and breast stroke with and without a PFD for 11.4 m (12.5 yds)? The sub questions included, (2) Will the addition of the PFD improve swim times?

Hypotheses:

Null Hypothesis 1

The average 11.4 meter American Crawl swim time in standard labor-wear with a PFD will be > than the average swim time without a PFD.

Research Hypothesis 1

The average 11.4 meter American Crawl swim time in standard labor-wear with a PFD will be < than the average swim time without a PFD.

Null Hypothesis 2

The average 11.4 meter elementary back stroke swim time in standard labor-wear with a PFD will be > than the average swim time without a PFD.

Research Hypothesis 2

The average 11.4 meter elementary back stroke swim time in standard labor-wear with a PFD will be < than the average swim time without a PFD.

Null Hypothesis 3

The average 11.4 meter yard breast stroke swim time in standard labor-wear with a PFD will be > than the average swim time without a PFD.

Research Hypothesis 3

The average 11.4 meter yard breast stroke swim time in standard labor-wear with a PFD will be < than the average swim time without a PFD.

Null Hypothesis 4

No flotation main effect

Research Hypothesis 4

Have a flotation main effect

Null Hypothesis 5

No stroke main effect

Research Hypothesis 5

Have a stroke main effect

Null Hypothesis 6

No stroke* flotation interaction effect (* = by).

Research Hypothesis 6

Have a stroke* flotation interaction effect.

Methods

We tested the hypotheses in a controlled indoor pool environment. Each subject swam two trials each of the three strokes, one trial was performed wearing standard labor-wear, including coveralls and boots and no PFD. The other trial was performed wearing standard labor-wear and a PFD. Thus, each subject swam six trials total. The PFD used was a United States Coast Guard Approved Type V PFD that provides about 20 lb of buoyancy (United States Coast Guard 2013). The labor-wear consisted of canvas coveralls worn over the subjects' swim-suit and steel-toed work-boots.

Nineteen volunteer subjects were chosen based on current or previous experience and credentials. The exclusion criteria were guided by the American College of Sports Medicine risk stratification process. American College of Sports Medicine (ACSM) guidelines suggest a pre-participation screening that identifies current medical conditions that would exclude those who are at risk for adverse cardiovascular, pulmonary, metabolic, as well as other conditions that would cause adverse responses to exercise (ACSM 2009). The list of conditions that excluded a subject included:

- Pregnancy
- Diabetes
- Hypertension or are taking blood pressure medication
- Asthma
- Concerns about safety of exercise or swimming ability
- Heart surgery
- Chest discomfort with exercise
- Unreasonable breathlessness with exercise
- Unexplained dizziness or fainting
- Musculoskeletal problems that limit functional capacity
- Current smoker

All subjects completed the pre-participation screening intended to identify anyone who should be eliminated. Additionally, all subjects chosen were under the age of 50 years.

Safety of the subjects for the swim was ensured in two ways. First, the swim was conducted in water that was 4 ft deep, in which all of the subjects were able to stand. The subjects were instructed to simply stand up if they were in distress. The subjects were surrounded by a lifeguard in the water and a lifeguard on the deck with appropriate rescue equipment as back-up measures.

The subjects read an informed consent form that emphasized the voluntary nature of this study and that if they were uncomfortable doing anything related to this study they had the option to not participate. The decision to take part in this research study was entirely voluntary and the subject could withdraw from the study at any time. Additionally, all procedures were presented to and authorized by, an institutional review board.

After the subjects read the informed consent form, they were informed of the order of the randomly selected trials. Each subject would swim each stroke with and without a PFD; we randomly assigned the order in which testing was carried out. Resting heart rate and blood pressure on each subject was measured prior to the start of testing and each subject was allowed to rest following each trial until heart rate and blood pressures reached their resting states.

The subject's heart rate was taken immediately following completion of each trial using an ADC Diagnostix 2100 pulse oximeter, as well as by palpation of the radial artery. Additionally, each subject's rating of perceived exertion was recorded. The subjects performed the next time trial when their heart rate and blood pressure returned to their resting norms.

Results

The mean 11.4-m American crawl swim time for subjects with PFD was 18.91 sec and mean swim time for the American Crawl without PFD was 23.29 sec. The Wilcoxon Signed Rank test generated a *P*-value of 0.0010. Thus, we rejected null hypothesis 1 in favor of research hypothesis 1 at a significance level of 0.05.

The mean 11.4 m back stroke swim time for subjects with labor-wear and PFD was 31.00 seconds and the mean swim time with labor-wear without PFD was 36.96 seconds. The Wilcoxon Signed Rank test for paired data generated a *P*-value of 0.0223 and, based on this result we rejected null hypothesis 2 in favor of research hypothesis 2 at a significance level of 0.05.

The mean 11.4 m breast stroke swim time for subjects with PFD was 22.61 seconds and the mean swim time without PFD was 23.006 seconds. The Wilcoxon Signed Rank for paired data produced a *P*-value of 0.2086. Based on this result we failed to reject null hypothesis 3 in favor of research hypothesis 3 at a significance level 0.05. That is, we have no evidence that the mean swim time for the breast stroke with PFD differs significantly from the mean swim time for breast stroke without a PFD (Fig 1), Swim Time Versus Stroke and PFD Use, shows a comparison of the three strokes with and without a PFD.

We also used a two-factor ANOVA with repeated measures on both factors. The repeated measure occurs because each swimmer was tested at every treatment. There are a total of 6 treatments (3 X 2 = 6). The factors used were:

1. Stroke, with 3-levels: crawl, back and breast
2. Flotation; with 2-levels: PFD and without PFD

The mean swim time for all swimmers without a PFD was 27.75 seconds and the mean swim time for all swimmers with a PFD was 24.17 seconds. A *P*-value of 0.0153 was computed. Thus, we rejected null hypothesis 4 in favor of research hypothesis 4 at a significance level of 0.05. Our results indicated that wearing a PFD increases average swim time, over all strokes, compared to not wearing a PFD.

The mean swim time for the crawl, overall, was 21.10 sec, the mean swim time

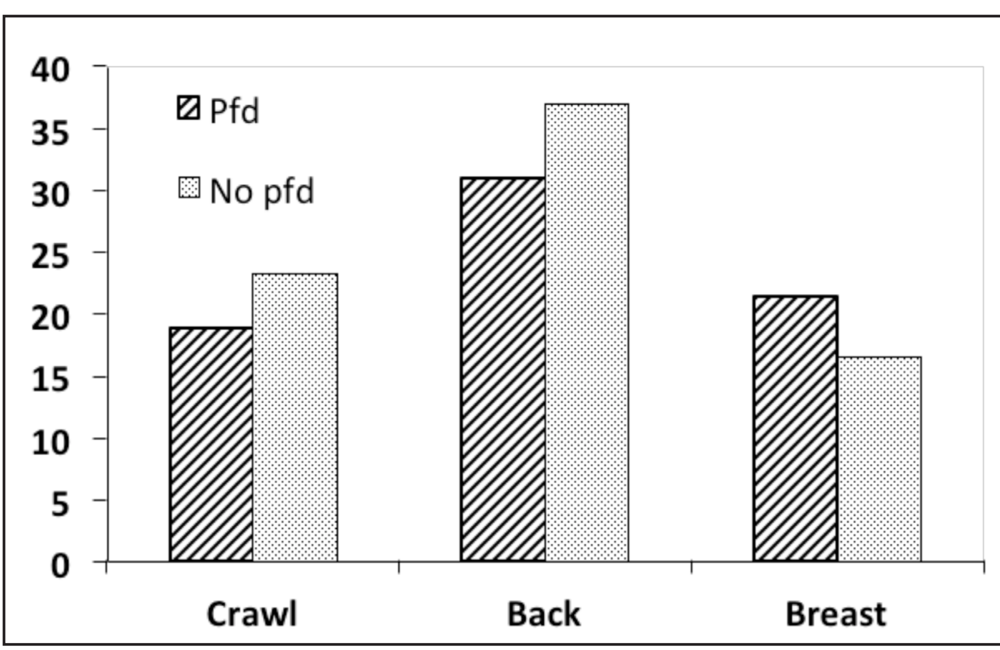

Figure 1. Comparison of swim times in seconds for all strokes with and without PFD.

for the back stroke, overall, was 33.98 sec and the mean swim time for the breast stroke with and without a PFD for all swimmers was 22.81. Based on a P-value of < 0.0001, we rejected null hypothesis 5 in favor of research hypothesis 5 at a significance level of 0.05. The stroke does have a main effect on swim times. Evidence indicates the mean swim time for swimmers using the elementary back stroke was slower compared to both crawl and breast stroke. In addition, there was no statistically significant difference between the mean swim time for the crawl stroke and the breast stroke.

Testing hypothesis 6 for a stroke X flotation interaction effect, we fail to reject the null hypothesis based on a P-value of 0.1640. We have no significant evidence of a stroke*flotation interaction effect. That is, we have no significant evidence that wearing a PFD will affect the three strokes in significantly different ways; the change to swim times was relatively consistent.

Discussion

Our results suggest that it is more efficient to swim 11.4 m in coveralls and work boots while wearing a personal flotation device as compared to making the swim when not wearing a personal flotation device. An individual who ends up in the water with standard labor-wear without a PFD should expect the physical requirements to swim for self-rescue to be more difficult than if they were wearing a PFD. Of the three strokes tested, the American crawl and the back stroke were significantly faster with the PFD.

When a person swims, it takes energy to stay on top of the water and to propel themselves forward (McArdle 2010). Labor-wear adds drag making swimming more difficult, so wearing a PFD will add more surface area creating extra drag (Parsons and Day 1986, Benjanuvatra et al. 2002, Vennell et al. 2006). The PFD keeps the person on top of the water so there is no need to expend energy to stay afloat and the person can use that extra energy to propel themselves forward, making the swim faster. However, wearing a PFD will not always ensure a successful self-rescue. The American Whitewater Affiliation keeps a database of deaths occurring on American rivers and from 2010-2013 13 deaths were reported on Montana creeks and rivers. Of the 13 fatalities, nine victims were wearing PFDs, two were not wearing a PFD and it was not reported whether the remaining two were wearing PFDs (American Whitewater Affiliation 2013).

The Whitewater Rescue Institute recommends using the defensive swim position, which involves floating on the back with feet downstream, to conserve energy and negotiate obstacles and hazards. They encourage aggressive swimming to self-rescue. For example, when swimming in a section of river with swift moving water and obstacles, it may be prudent to lie back in the defensive swim position, keeping the feet on the surface of the water to avoid foot-entrapment while steering with the arms. When an opening is encountered to reach a safe location, aggressively swimming to that spot may be necessary to avoid drowning (Harris and Johnston 2011). This may involve staying on the back and aggressively swimming using a back stroke or turning over from the defensive swim position to be able to use the American crawl or the breast stroke, or any other stroke.

Our research indicated that the fastest stroke was the American crawl, followed by the breast stroke and elementary back stroke, respectively. This was true whether a PFD was worn or not, though we detected no difference between the breast stroke times.

The limitations to this study included a small sample size, age of the subjects and lack of objective fitness data. Most of the subjects were of a young age ranging from 20 to 38 yrs and only one subject was > 40 years old, which may not accurately reflect the average age of the work-force. The subjects were relatively fit with some being collegiate athletes, firefighters and this also may not be a true representation of the work-force. Also, the labor-wear only consisted of boots and the coveralls; no inner layers were worn. Insulation layers may have had a further impact on the measurements. The environment was controlled; the water was warm, clear and non-moving when, in reality, many water incidents occur in cold, dark moving water.

Suggestions for Future Research

To gather more information, conducting fitness assessments on, each subject would be beneficial. Also, adding the insulation layers that are normally worn may more accurately reflect a laborer's physiological response in water. Monitoring heart rates and oxygen consumptions and comparing the different strokes would provide information on energy expenditure. It would also be important to compare the effect of different water temperatures on swim times and strokes.

Practical Application

When recreating or working on or near water where there is a drowning hazard, wearing a PFD will ensure an easier self-rescue. The Occupational Safety and Health Administration requires workers to wear a PFD when working near a drowning hazard and we recommend that employers strictly follow that requirement. Simply wearing a personal flotation device will improve the efficiency of self-rescue, making swimming easier. However this rule is not always followed and wearing a PFD will not always prevent the loss of a life. Based on the results of this study, we believe it is beneficial for those who work on or near water to always wear a PFD. If there is a need for self-rescue we recommend using the stroke with which the person is most comfortable. The American crawl was the fastest, but also appeared to be the most exhausting, so distance to safety may need to be considered during self-rescue.

We also recommend that any company requiring their employees to work on or near water consider implementing water safety plans that may include swift water rescue professionals to conduct training and to be on-site to help prevent water injury and death. Finally, we recommend training that allows in-water experiences so employees develop an understanding of their abilities and limitations and practice the different strokes in the water to find out which stroke they are most comfortable with if water-based self-rescue is required.

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