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Efficacy of Flotation Aids Attached to the Pelvis and Thighs of Beginning Swimmers

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Cover Page Footnote

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Abstract

The study aimed to experimentally verify the efficacy of wearing flotation aids to add buoyancy from the pelvis to the side of the thigh on the swimming performance of beginning swimmers who were capable of swimming around 25 meters at a time. The study recruited seven male university students who were members of the Physical Education Department and who lacked experience in specialized swimming instruction. The study found statistical difference in prone flotation between the use of flotation aids (7.27±1.92 sec) and without flotation aids (3.50±0.72 sec). During swimming for distance in a 5 min. swim test, we found statistical differences between the use of flotation aids (185.0±29.6 m) and without flotation aids (172.6±24.4 m). Moreover, no overall differences in stroke length and stroke rate were observed between flotation and no flotation use conditions.

Keywords: flotation device, front crawl, breaststroke, swimming speed, stroke length, stroke rate, swimming performance

Introduction

Maintaining a horizontal body position during swimming is an important factor that is directly linked to performance especially in competitive swimming. In this position, the center of buoyancy (CoB) rests toward the cranial (i.e., head) end of the prone body, whereas the center of gravity (CoG) rests on the caudal (i.e., pelvic or lower) side (Hay, 1993). Therefore, when a person remains still in the water, underwater torque acts downward against the center of gravity, which causes the lower extremities of the body to drag (Watanabe et al., 2017). When in a streamlined posture, even if there is no difference in height or weight, beginning swimmers frequently encounter difficulties in maintaining a horizontal position because their centers of buoyancy and gravity are much further apart vertically than those of expert swimmers (Watanabe et al., 2014). At a swimming speed of 0.4–0.7 m/s, the torque and the energy cost that is expended on caudal drag occur simultaneously with the majority of energy consumption being allocated for maintaining the horizontal posture (Capelli et al., 1995). At a swimming speed of 1.00–1.23 m/s, the torque exerted on the lower extremities increases by 73%, which results in linear increases in energy cost and active body drag (Zamparo et al., 1996). Adding buoyancy by using a wet suit reduces swimming time (Cordain & Kopriva, 1991), oxygen intake, and blood lactic acid levels (Chatard et al., 1995). Thus, an overview of previous studies suggests that swimming can become easier and more efficient if moderate buoyancy is added to the body to suppress caudal drag and maintain a horizontal body position (i.e., a high position by CoG in the water).

In terms of competitive swimmers, the buoyancy torque that acts on the body and the torque generated by kicking against the water with the feet help to lift the legs, whereas the torque generated by sculling the water with the hands generates drag on the lower limbs (Yanai, 2001). Although such effects are less recognizable in beginning swimmers given the down-sweep of sculling in the upper portion of the body and the downward force generated by the downward kick of the lower extremities on the center of gravity (Yanai, 2001), even beginning swimmers undoubtedly maintain balance by generating a complex torque in different directions. In terms of kinematics, however, multitasking may be challenging for beginning swimmers because it generates different torques in the arms and legs.

A “helper” is a flotation aid that helps beginning swimmers learn how to swim. Although its shape differs depending on the manufacturer, the helper generally features a string or belt threaded through buoyancy objects, such as polyethylene blocks. The helper is then wrapped around some portion of the torso or thighs. These helpers are present at many swimming sites. Adding buoyancy around the pelvis helps the body float because it positions the center of gravity closer to the surface of the water which in turn reduces drag from the pelvic and lower extremity regions. During full-body swimming, the centers of buoyancy and gravity constantly move back and forth in the direction of the head and feet. Because the center of buoyancy shifts more dramatically than the center of gravity during full-body swimming (Cohen et al., 2014), if a large block-shaped buoy is placed around the waist of a beginner-level swimmer (i.e., near the center of buoyancy and the center of gravity) to keep the body afloat, the strong buoyancy may generate sufficient torque that can cause the swimmer’s feet to either sink or float considerably, as their center of buoyancy shifts during full-body swimming in a complicated manner. This does not further the original purpose of using an assistant who can help beginner-level swimmers learn how to swim. On the contrary, this raises concerns that it may increase difficulty in swimming. To prevent this phenomenon, one solution is to affix substantially slim flotation aids that fit the body on the left and right sides of the pelvis. Flotation aids that add buoyancy from the pelvis to the thighs generate an upward buoyancy torque that lifts the legs which may reduce the burden of the kicking task.

The present study aimed to verify the effects of buoyancy added from the sides of the pelvis to the sides of the thigh on beginning swimmers. Moreover, the effects of flotation aids on swimming performance for a duration of 5 min and a sprinted swimming distance of 25 meters were examined.

Method

Participants

The participants in the study were seven healthy male university students who were students of the Physical Education Department. These participants were only able to swim around 25 meters at a time and had no prior experience with specialized swimming instruction (apart from basic swimming classes taught in physical education (average age: 19.3 ± 0.5 years: height: 1.72 ± 0.05 m; and weight: 75.3 ± 21.1 kg) (see Table 1).

All the participants received verbal and written explanations of the objectives and experimental content of the research, the advantages and disadvantages of research collaboration, and the anticipated publication of research results. The participants provided written informed consent. In accordance with the principles of the Helsinki Declaration, the study was conducted with the utmost ethical consideration for the participants and with the approval of the ethics committee of the affiliated organization.

Table 1
Participant characteristics (n = 7): FA refers to differences in the buoyancy of the flotation aids; Style refers to differences in the swimming techniques or strokes

Participant	Age (yrs)	Height (m)	Weight (kg)	FA (N)	Style (stroke)
A	19	1.81	119.0	15N	Breaststroke
B	19	1.69	71.2	15N	Breaststroke
C	19	1.68	60.4	15N	Breaststroke
D	19	1.72	58.5	15N	Crawl
E	19	1.75	84.6	10N	Crawl
F	20	1.67	67.4	15N	Crawl
G	20	1.70	65.8	10N	Crawl
Mean	19.3	1.72	75.3		
SD	0.5	0.05	21.1		

Overview of the Flotation Device
Two types of flotation aids were used, namely, 10N and 15N. The researcher selected the type based on the physique of a participant (Figure 1).

Figure 1
Appearance of flotation aids and other equipment as worn by the participants (during the assessment of prone flotation)

Buoyancy pads were molded from a polypropylene material with a foam ratio of 30 times (30 kg/m3), which resulted in 1,000 cm3 (1.0 liters) and 1,500 cm3 (1.5 liters) for the 10N and 15N, respectively. The flotation aid was attached to the trochanter major on both sides of the participant's pelvis with a nylon belt that passed between the pelvis and inguinal region and was fastened with a D-ring. The buoyancy pads were embossed in a cross shape vertically and horizontally to conform to the curvature of the participant's body.

Assessment of Prone Flotation

The study evaluated prone flotation by measuring the time lapsed until the participant's toes touched the bottom of the pool (water depth: 1.4 m). The participant started in a glide posture and used both hands to hold a rotary handle installed under the surface of the water. A research assistant helped the participant keep their feet afloat on the surface of the water. Upon the start signal, the research assistant released their feet, and the participant attempted to maintain a horizontal position on the surface of the water as long as possible while holding the rotary handle. During measurement, the participant maintained a stationary float from beginning to end. The participant breathed through a center snorkel and wore a nose clip to prevent air from leaking from the nose.

Assessment of the Five-Minute Swim

The five-minute swim was conducted in an eight-lane, 25-meter indoor pool (water temperature: 29°C; water depth: 1.4 m). The duration of warm-up exercises for participants was 30 minutes. All the participants prepared for the test by moving their bodies freely in accordance with their respective skills and levels of physical fitness. The participants swam continuously from start to finish using one technique of their choice with and without flotation aids for as long as possible. The participant begun the test from an in-water push-off. Moreover, the participants were instructed to reduce rest time as much as possible. The tests were conducted without flotation aids to all the participants in the first trial, and with flotation aids attached in the second trial. Both tests were completed on the same day. The participants were given one hour of rest between tests. During the break period, they worked on recovery based on their preferred technique and depending on their level of fatigue. The total distance was measured per participant, and their heart rates were recorded from start to finish per second using a heart rate monitor (RS400, Polar Electro Oy, Kempele, Finland). The maximum, minimum, and average heart rates were calculated. In addition, the participant's rating of perceived exertion (RPE) after exercise was calculated using the Japanese RPE scale created by Onodera and Miyashita (1976) which was based on Borg's original RPE scale. The center snorkel and nose clip were not worn during the 5-min test.

Assessment of the 25-Meter Swim

The 25-meter swim was conducted in the same eight-lane, 25-meter indoor pool (under the same conditions as the five-minute swim) with the same water temperature and water depths as the five-minute swimming stroke test. The duration of warm-up exercises for participants was 30 minutes, the same as the five-minute swim test. All the participants prepared for the test by moving their bodies freely in accordance with their respective skills and levels of physical fitness.

The participants were instructed to swim as fast as possible using one type of stroke of their choice from start to finish regardless of the presence or absence of flotation aids. The participant begun the test from an in-water push-off as same as the five-minute swim. The tests were conducted without flotation aids attached to all the participants in the first trial, and with flotation aids in the second trial. Both tests were completed on the same day along with the five-minute swim test. The participants were given one hour of rest between tests. During the break period, they worked on recovery based on their preferred technique, depending on their level of fatigue. The time elapsed was recorded. A video camera (GZ-RX680-D, JVCKENWOOD Corporation, Yokohama, Japan) was used to record the participants' swimming speed and stroke length at a rate of 30 frames per second. A side view of each participant was recorded over a 7.5-meter section from the center of the pool to 5 meters from the end of the wall. The study considered the effect of the skill of the swimmer's starting push-off technique on stroke index. Thus, the first 12.5 meters from the starting point to the pool's center line were excluded from analysis. The footage was analyzed using Video Performance Monitor-Swim (VPM-D, Yokohama Sports Development Institute, Yokohama, Japan). In the same manner as the 5-min test, the center snorkel and nose clip were not worn during the 25-meter swim test.

Statistical Analysis

The distribution of all the results were confirmed as normal in accordance with the Shapiro–Wilk test of normality. Mean and standard deviations were derived for each individual participant's values. The mean of each measured value with and without flotation aids was compared by calculating Student's dependent t-test with a confidence interval of 95% (95% *CI*). For effect size, Cohen's d was calculated with reference to Cohen (1988) where 0.2 = small effect size, 0.5 = medium effect size, and ≧0.8 = large effect size. The significance level for Type I errors was set to 0.05 for each test calculated. IBM SPSS Statistics 27 (IBM Corporation, Armonk, NY, USA) software was used to calculate the statistical analyses.

Results

The confidence interval for the difference in mean float time with and without flotation aids was 95% *CI* [-5.55, -2.00]. A duration of 7.27±1.92 sec with flotation aids demonstrates a statistically significant greater value than the 3.50±0.72 sec without flotation aids (t (6) = -5.208, p = 0.002, d = 2.82).

Table 2 provides the average and standard deviation results for swimming distance and stopping time for each participant in the five-minute swim test. The confidence interval for the difference in the average swimming distance of 5 min with and without flotation aids was 95% *CI* [-18.42, -6.44]. A distance of 185.0±32.0 meters with flotation aids demonstrated a statistically significant greater value than a distance of 172.6±26.3 meters without flotation aids (t (6) = -5.077, p = 0.002, d = 0.46). The confidence interval for the difference in the mean stopping time was 95% *CI* [-18.90, 20.93], with a non-statistically significant difference between 70.6±68.0 s with flotation aids and 71.6±64.6 s without flotation aids (t (6) = 0.125, p = 0.905, d = 0.02).

Table 2
Comparison of distance swam and stopping time over 5 min based on the presence or absence of flotation aids per participant

Participant	Swimming distance (m)		Stopping time (sec)	
	w/o FA	w/ FA	w/o FA	w/ FA
A	139	147	0	5.3
B	162	169	21.5	17.0
C	150	158	0	0
D	169	184	133.1	111.1
E	200	215	79.7	53.9
F	175	184	113.4	153.3
G	213	238	153.3	153.3
Mean	172.6	185.0	71.6	70.6
SD	26.3	32.0	64.6	68.0
95% *CI*	[-18.42, -6.44]		[-18.90, 20.93]	
t value	-5.077		0.125	
p value	0.002		0.905	
Cohen's d	0.46		0.02	

The confidence interval for the difference in the mean value of RPE with and without flotation aids was 95% *CI* [-1.89, 2.17]. The study observed no statistically significant difference between 17.0±2.0 and 17.1±2.9 with and without flotation aids, respectively (t (6) = 0.172, p = 0.869, d = 0.04). The confidence interval for differences in the mean values of the maximum heart rate with and without flotation aids was 95% *CI* [-8.45, 1.88], minimum heart rate with and without flotation aids was 95% *CI* [-15.64, 14.79], and average heart rate with and without flotation aids was 95% *CI* [-6.36, 0.94] with no statistically significant differences between 174.4±15.5 and 171.1±19.9 bpm, between 110.1±18.6 and 109.7±10.2 bpm, and between 158.6±16.7 and 155.9±15.7 bpm with and without flotation aids, respectively (maximum: t (6) = -1.555, p = 0.171, d = 0.20; minimum: t (6) = -0.069, p = 0.947, d = 0.03; average: t (6) = -1.820, p = 0.119, d = 0.17).

Table 3 presents the results of the average and standard deviation for swimming time, swimming speed, stroke length, and stroke rate of 25 meters for each participant. The confidence interval for the difference in average swimming time of 25 meters was 95% *CI* [-1.69, 1.57] with a non-statistically significant difference between 23.86±6.37 and 23.80±7.16 s with and without flotation aids, respectively (t (6) = -0.086, p = 0.934, d = 0.01). Further, the confidence interval for the difference in the average swimming speed of 25 meters was 95% *CI* [-0.03, 0.08], with a non-statistically significant difference between 0.94±0.27 and 0.97±0.28 m/s with and without flotation aids, respectively (t (6) = 1.119, p = 0.306, d = 0.12). The confidence interval for the difference in average stroke length was 95% *CI* [-0.21, 0.14]. The study observed a non-statistically significant difference between 1.46±0.42 and 1.42±0.27 m/stroke with and without flotation aids, respectively (t (6) = -0.474, p = 0.652, d = 0.12). The confidence interval for the difference in average stroke rate was 95% *CI* [-3.46, 5.75], with a non-statistically significant difference between 39.13±4.17 and 40.28±4.70 strokes/min with and without flotation aids, respectively (t (6) = 0.607, p = 0.566, d = 0.28).

Discussion

The study inferred that the increased time for prone flotation was the result of a reduction in the amount of negative buoyancy on the lower extremities that causes them to sink. Therefore, the study concluded that the use of flotation aids contributed to the increase in buoyancy of the thigh, which contains a large amount of bone and muscle, is reasonable. The reason underlying this mechanism is that the buoyancy of the flotation equipment was located below the navel which generally represents the center of gravity of the human body.

In terms of the five-minute swim test, no significant differences in the RPE and maximum, minimum, and average heart rates were observed. Therefore, the study concluded that the participants swam with the same amount of effort regardless of the presence of flotation aids. The ability of all the participants to swim greater distances when wearing flotation aids is presumed to be due to the reduced caudal drag provided by the increased buoyancy. The statistical effect size generated by flotation aids was moderate. With the effect size positioned within a normal range, a power analysis of $\alpha = 0.05$, $1 - \beta = 0.8$ suggested a sample size of approximately 30 would have been needed to find significance at $\alpha = 0.05$. In other words, making a judgment based solely on the significant differences herein was impossible due to the small sample size, and further detailed verification is required.

In addition, no difference in stopping time was observed. Two participants did demonstrate increases in stopping time when wearing flotation aids. Participant A stopped for 5.3 s, which accounted for approximately 1.8% of the 5-min swim time which consumed a total of 300 seconds. Therefore, the study inferred that no change in stopping time occurred. Participant F stopped for 39.9 s or 13.3% of the total 300 s. The relevance of this result to the study remains unclear. Moreover, the discussion should be appropriately limited owing to the small sample size and low statistical power to discover a difference.

In terms of the differences in swimming style, the swimming distances when wearing flotation aids were deemed longer for the crawl than for the breaststroke which should not be surprising given the differences in the two strokes. The stop times varied individually depending on the participant. Despite this allowance, however, the participants could swim the crawl much faster when wearing flotation aids than they could swim the breaststroke. Cordain and Kopriva (1991) found that swimming time was slower when competitive swimmers wore wetsuits and neoprene bands wrapped around the calves compared to simply wearing a

Table 3
Comparison of swimming time, swimming speed, stroke length and stroke rate of 25 meters based on the presence or absence of flotation aids per participant

Participant	Swimming time (sec)		Swimming speed (m/s)		Stroke length (m/stroke)		Stroke rate (strokes/min)	
	w/o FA	w/ FA	w/o FA	w/ FA	w/o FA	w/ FA	w/o FA	w/ FA
A	34.88	33.06	0.62	0.60	1.00	0.95	37.26	37.85
B	29.65	27.48	0.72	0.75	1.16	1.00	37.50	45.45
C	27.90	29.90	0.77	0.70	1.38	1.20	33.42	35.19
D	19.04	19.86	1.12	1.10	1.65	1.94	40.81	33.99
E	16.06	18.39	1.33	1.22	1.71	1.70	46.69	43.01
F	22.25	22.24	0.97	0.93	1.42	1.49	40.81	37.50
G	16.83	16.08	1.25	1.31	1.65	1.93	45.45	40.95
Mean	23.80	23.86	0.97	0.94	1.42	1.46	40.28	39.13
SD	7.16	6.37	0.28	0.27	0.27	0.42	4.70	4.17
95% *CI*	[-1.69, 1.57]		[-0.03, 0.08]		[-0.21, 0.14]		[-3.46, 5.75]	
t value	-0.086		1.119		-0.474		0.607	
p value	0.934		0.306		0.652		0.566	
Cohen's d	0.01		0.12		0.12		0.28	

swimsuit. Thus, a possible aspect is that the added buoyancy lifted the legs to a position higher than their optimal position in the water. As Yanai (2001) mentioned, competitive swimmers balance hydrodynamic forces by generating buoyancy through leg kicks and sculling using their arms. Thus, the study infers that an additional, excessive buoyancy on the calves may interfere with this balance. Whether the same can be applied to beginning swimmers remains unclear. Visualizing that beginning swimmers experience a considerably greater drag on the legs than competitive swimmers do is straightforward. Furthermore, the less skilled kicking skills of beginning swimmers indicate that the hydrodynamic forces generated by the arms and legs are unbalanced in the first place. Thus, maintaining posture may be difficult because the distance between force points that "generate downward force," as Yanai noted, is far. Therefore, concluding that an additional upward force can be applied between the force points of the arms and between those of the legs across the center of gravity by attaching flotation aids from the pelvis to the thigh is natural. Thus, maintaining posture with flotation aids is easier than without.

In the 25-meter swim, the study observed no statistical differences in the swimming time, swimming speed, stroke length, and stroke rate. Notably, however, the stroke index featured certain tendencies dependent on the style (i.e., the breaststroke or the crawl). Reviewing the individual results, the study found that the stroke length decreased in the breaststroke but increased in the crawl, whereas the stroke rate increased in the breaststroke but decreased in the crawl with flotation aids. Leblanc et al. (2009) observed that nearly no glide phase is noted for recreational swimmers using the breaststroke compared to competitive swimmers. The reasoning underlying this finding is that recreational swimmers kick when they should glide. In addition, the aforementioned study observed that, during sprint phases, stroke rate may increase as arm propulsion begins to overlap while the body accelerates from the kick of the legs, which possibly increases resistance.

Resistance during swimming increases exponentially with the second and third powers of velocity (Wakayoshi et al., 1995): the faster one tries to swim, the greater the resistance becomes. The breaststroke is the only one of the four swimming techniques wherein the arms and legs recover underwater. A well-known fact in breaststroke is that the recovery of the thighs exerts a large effect on resistance. In the current study, the shortening of the stroke length when wearing flotation aids indicates that the float may contribute to an increased resistance. Moreover, this study proposed that the increase in the stroke rate was a result of compensating for the decrease in the swimming speed owing to an increased resistance from the flotation aid. By contrast, the constant movement of the limbs coming out of the water propels the body forward during the crawl. The increased stroke length and decreased stroke rate suggested that the benefits of wearing flotation aids during the crawl outweigh the increased resistance.

Yanai (2001) found that among competitive swimmers using the crawl, the upper portion of the arms generates a torque that increases drag on the legs, whereas the kick generates the torque required to lift the leg, both of which work to cancel each other. Yanai noted that this mechanism maintains balance while swimming. Whether the same can be said for beginning swimmers is still unclear. In any case, even for beginning swimmers, kicking undoubtedly contributes to the torque that acts on the legs. Regardless of the mechanism that led to the results herein, swimmers may require less effort to kick because flotation aids generate a torque that also lifts the legs independent of the kicking action. Thus, although several tendencies were observed in the differences between the two swimming strokes, the fact remained that no significant statistical differences in the swimming time, swimming speed, stroke length, and stroke rate could be attributed to the influence of the characteristics of the swimming stroke.

Limitations of the Study

The recruited participants were only able to swim for a maximum distance of 25 meters. Moreover, the study considered the unique characteristics of each participant. A difference was noted between the swimming strokes (i.e., the breaststroke and the front crawl). Differences in effect based on stroke could not be verified statistically because of the small sample size and low statistical power. Therefore, further validation is required to clearly demonstrate the effect of flotation aids on swimming performance. In addition, the effects of torque on the centers of buoyancy and gravity referenced earlier in this paper were based on investigations of competitive swimmers. Consequently, verifying whether applying such conditions is appropriate for beginning swimmers is still necessary to demonstrate. In the future, it is important to investigate the effect of torque on the centers of buoyancy and gravity among beginning swimmers during full-body swimming.

Conclusion

The study examined the effects of attaching flotation aids with moderate buoyancy to the pelvis and thighs of young adult beginning swimmers with the aim of assessing increased buoyancy during stationary prone flotation, a five-minute swim, and a 25-meter swim for speed. The results clearly demonstrated that affixing flotation aids with appropriate buoyancy enabled beginning swimmers to float longer on the surface of the water and swim for greater distances and longer periods of time, but not to swim faster.

The effects of wearing flotation aids during full-body swimming may differ depending on the swimming style employed. Although the benefits of flotation were generally considered greater for the crawl than those for the breaststroke, further study is required in this regard. The flotation aids developed for the study can be used as future kinematic tools for beginning swimmers and hopefully can contribute to improvements in the swimming skills of beginning swimmers.

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