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The effects of land-based plyometric training and timing of plyometrics fusion on selected acute swim performance measures

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Senior Honors Research Proposal

by

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Working Title: The effects of land-based plyometric training and timing of plyometrics fusion on selected acute swim performance measures

Purpose and guiding hypothesis

The purpose of this study is twofold: 1) to determine the effect of land-based plyometric training on selected acute swim performance measures; and 2) to determine the effect of timing on acute swim performance measures when incorporating plyometric training into a single training session. The guiding hypothesis for this project is that the land-based plyometric training will have a positive impact on acute swim performance, in particular when the plyometrics are performed pre-training session (compared to mid-training session).

Relevance of the research

Historically, plyometric training (PT) was predominately practiced by elite athletes, such as Olympians, for sport performance enhancement. Recently, incorporating plyometrics into the training regime has caught the attention of sub-elite and recreationally competitive athletes, in particular those participating in weight-bearing sports such as running and jumping, and less so in non-weight bearing sports such as cycling and swimming. Since many swimming events rely on explosiveness, speed, and power, it is understandable that plyometric training supplementation has been used by swimmers and coaches to improve performance.

However, debate has been generated on the use of PT and the effects it may have on acute and chronic adaptations and performance. Additionally, discussions have taken place regarding the proper timing of incorporating PT (pre-practice vs. during practice vs. in isolation) and the transfer effect of land-based PT to water-based sports. To date, there is little to no research evaluating the effect of land-based plyometric training on acute swim performance, the appropriate timing to optimize performance, and if a transfer effect exists. Hence, there is a need for more studies to evaluate the effectiveness, timing and transferability of PT on acute swim performance. This theoretical and clinically applicable information would be useful for sport practitioners, including athletes, coaches, and strength and conditioning specialists, and would serve as a foundation for additional research conducted on the use of PT.

Review of Literature

Plyometrics (aka “plyos” or “jump training”) are exercises incorporated into a training program used to enhance an individual’s speed, explosiveness, and power output after development of a strong strength base (Chu et al., 1984). These specialized (dynamic correspondence) exercises are based around having muscles exert maximum force in as short a time as possible, yielding an advantage in any sport requiring high ground reaction forces that are executed in an extremely quick and explosive manner. These improvements are obtained by optimizing the stretch-shortening cycle, which occurs when the active muscle switches from rapid eccentric muscle action (deceleration) to rapid concentric muscle action (acceleration)(Wilk et al., 1993). The more quickly the muscle can transition from a forcefully lengthened muscle to a shortened muscle after being pre-tensed, the greater the muscle will respond explosively (Svantesson et al., 1994). To improve these stretch-shortening cycle capabilities within muscle (i.e. learning to move from a muscle extension to a contraction in a rapid way), specialized repeated hops, skips, and jumps can be used (Chu et al., 1984). Given the evidence suggesting the effectiveness of plyometrics on performance outcomes, plyometric training (PT) has obviously gained popularity among elite and sub-elite athletes, and in the fitness field to a lesser degree.

Previous studies have found that PT has improved performance in both men and women (Hewett et al., 1996, NSCA 1993), as well as in athletes of varied sports (LaChance, 1995, Wathen, 1993). The majority of studies have evaluated the effectiveness of PT in sports involving sprinting and/or jumping activities (Gambetta, 1998, Wathen, 1993). This is logical since sprinters need to execute with as much force as possible the switch from the eccentric contraction when the foot hits the ground to the concentric contraction when the foot breaks contact with the ground, and jumpers need to achieve as much height as possible by minimizing the time between receiving the forces and giving the forces back.

The use of PT in swimming is a relatively new avenue for performance enhancement; therefore, little systematic research on its effectiveness has been conducted to date. Potdevin *et*. al (2011) showed a direct improvement in swim performance amongst pubescent swimmers following a six week land-based plyometric training (LBPT) program. Specifically, the PT was shown to positively increase gliding speed and average acceleration. In contrast, research has shown that PT training utilizing highly focused, intense movements used in repetition increases the potential of acute fatigue, overtraining, and chronic level of stress on joints, potentially leading to injury (LaChance, 1995, Wilson et al., 1993). Additionally, even less evidence has been published examining the relationship between supplemental LBPT on acute swim performance only (Donaghue et al., 2011, Triplett et al., 2009), as well as the proper timing of incorporating PT during a single training session. Regardless of the lack of scientific data to support or dismiss the use of PT to improve swim performance, swim coaches and swimmers alike are beginning to incorporate LBPT during the strength/intensity portion of the training cycle and/or perform such specialized exercises during the competition phase during the swim practice itself.

The lack of data points to the uncertainty of whether or not LBPT has a negative or positive effect on acute swim performance. Since many swimming events rely on explosiveness, speed, and power, it is understandable that LBPT supplementation may be a great investment for improving performance. Therefore, the purpose of this study is twofold: 1) to determine the effect of land-based plyometric training on selected acute swim performance measures; and 2) to determine the effect of timing on acute swim performance measures when incorporating plyometric training into a single training session.

Methodology

Thirty intermediate- to advanced-level swimmers from Prince Edward County High School swim team and the Longwood University club swim team will be recruited for this study. Due to the nature of the intervention protocol, inclusion criteria for participants will include a required capability to swim freestyle stroke for a total of 700 meters without difficulty (7 laps/14 lengths in a 50m pool).

The hypothesis in question will be determined by using an intervention methods approach. All swimmers will complete three training sessions consisting of a freestyle swimming ladder drill, with two of the training sessions consisting of supplemental land-based plyometric training (LBPT). A ladder drill is composed of an increase in volume of each swimming bout to a specific apex followed by a decrease in volume until the starting point.

Control (C) training session. Participants will complete the following ladder drill: 50 m, 100 m, 200 m, 200 m, 100 m, 50 m. No LBPT will be performed during this training session. Times will be recorded for each trial, and stroke count will be measured for the last 50 m trial. Recovery time allotted between each trial will be prescribed using a 1:2 work-to-rest ratio. For example, if the swimmer completes the 50 m swim in 25 seconds, then the individual will have 50 seconds to recover before beginning the 100 m portion of the test. This ratio has been selected because of the time needed for the body to adequately restore creatine phosphate, ATP, and glucose, among other variables, before the onset of another interval (Wilson et al., 1996).

Pre-land-based plyometric training (PreLBPT) session. This protocol will involve the participant performing the LBPT *before* completing the ladder drill in the pool. The sequence will be as follows: LBPT, 50 m, 100 m, 200 m, 100 m, 50 m. To substitute for the energy expended and volume of work performed during the LBPT, the first 200 meter bout will be removed from the test. The average time for the two 200 m swims from the control training session will be used to determine the length of time the participant performs the LBPT. [Compared to each other, PT and swim performance do not have identical metabolic demands, but with the removal of the 200 meter bout, the difference should be insignificant.] Times will be recorded for each trial, and stroke count will be measured for the last 50 m trial. Recovery time allotted between each trial will be prescribed using a 1:2 work-to-rest ratio.

Mid-land-based plyometric training (MidLBPT) session. This protocol will involve the participant performing the LBPT *during* the ladder drill. The sequence will be as follows: 50 m, 100 m, 200 m, LBPT, 100 m, 50 m. Once again, a 200 m bout will be removed to substitute for the energy expended during the LBPT. Times will be recorded for each trial, and stroke count will be measured for the last 50 m trial. Recovery time allotted between each trial will be prescribed using a 1:2 work-to-rest ratio.

The land-based plyometric training will be targeted to the large muscle groups in the shoulders, legs, chest, and back. These muscle groups are the main force propelling the swimmer forward, so they will be the ones concentrated on for testing. The plyometric drills will include the following: alternating scissor hops, cycle kicks, overhead med ball toss reactive, oscillatory push-up, lateral deltoid rebound, band internal external shoulder, band tricep extension, and delt bent over lateral reactive drop. The technique for each plyometric will be demonstrated prior to the participant completing the exercises.

Each participant will perform 6-10 reps of each plyometric, depending on the time allotted for the PT session.

The PreLBPT and MidLBPT training sessions will be randomized across subjects to minimize the learning curve. Additionally, a minimum of 3 days and maximum of 7 days will separate each training session. Every participant will perform all three training protocols since the nature of this study is not to compare the swimmers to one another, but rather to analyze the individual's swim performance and the potential benefits or impedance of LBPT. Therefore, the total number of strokes counted during the last 50m trial of each training session and all swim trial times recorded for each individual during each training session will be used for individual comparison only. Analysis of Variance (ANOVA) will be used to analyze the effects of LBPT on acute swim performance.

Modified Methodology. An additional experiment was developed to determine if a decreased work-to-rest ratio time would induce fatigue. This protocol involved only a modified work:rest ratio, from 1:2 to 1:1. To illustrate an example of these protocols, in the first experiment if the swimmer completed a 50 m swim in 25 seconds, then the individual had 50 seconds to recover before beginning the 100 m portion of the test. In the second experiment, if the swimmer completed a 50 m swim in 25 seconds, then the individual had 25 seconds to recover before the next portion of the test.

Materials and resources

Materials required to conduct the study:

1. Detecto® calibrated scale to measure the individuals' weight and height before each training session.
2. Lap pool (25m or 50m). Both Longwood University's pool (Willett Hall) and Prince Edward High School's pool will be used.
3. Champion Sports® hand-held stop watch to measure trial times.
4. Bodylastics® resistance bands for plyometric exercises (available in the Exercise Physiology laboratory)
5. Premium Power® plyometric boxes for plyometric exercises (available in the Exercise Physiology laboratory)
6. Valeo® Medicine balls for plyometric exercises (available in the Exercise Physiology laboratory)

Results

All statistical analyses were completed using the SPSS version 22 (SPSS, Inc., Chicago, IL) statistical software package. Six, 1x3 (group x intervention) analysis of variance, were performed to determine if a statistical significance was present across all three interventions for each of the six primary outcome variables (time at 1st 50m, 1st 100m, 1st 200m, 2nd 100m, 2nd 50m, and Stroke Count). The alpha level of $P < 0.05$ was the minimum level to reject the null hypothesis. Means and standard deviations for each outcome variable for the sessions involving the 1:2 work:rest ratio are included in Table 1. No main effects from the intervention were noted and the F-values and corresponding p-values are also included in Table 1. *Post-hoc* Tukey t-tests were performed to determine if statistically significant differences existed between interventions (Control vs. Pre-Plyometrics, Control vs. Mid-Plyometrics, and Pre-Plyometrics vs. Mid-Plyometrics). No significant differences were noted with t-values and corresponding p-values found in Table 2.

Identical statistical tests were performed for the sessions involving the 1:1 work:rest ratio. No main effect of intervention was found (F-values and corresponding p-values are in Table 3), nor were any significant differences noted between interventions in the *post-hoc* Tukey tests (t-values and corresponding p-values are in Table 4). Based on the statistical analyses of both the 1:2 and 1:1 work:rest ratio, we are unable to reject the null hypotheses that plyometric exercise would not affect swim times nor stroke count.

Table 1 (1:2 Work: Rest Ratio)

Distance	Control Time (s)	Pre-Plyo Time (s)	Mid-Plyo Time (s)	F-values	P-values
1st 50 m	42.27 ± 3.17	41.32 ± 4.43	41.55 ± 3.12	.187	.831
1st 100 m	89.28 ± 7.42	89.89 ± 9.54	89.97 ± 7.37	.021	.979
1st 200 m	186.99 ± 16.11	190.75 ± 19.85	189.26 ± 16.03	.118	.889
2nd 100 m	89.15 ± 8.50	91.43 ± 9.35	89.17 ± 7.35	.241	.787
2nd 50 m	42.07 ± 4.14	42.67 ± 4.80	41.35 ± 4.45	.218	.805
SC 50 m	38.40 ± 5.04	39.30 ± 5.66	39.80 ± 5.59	.170	.844

Values are given as mean ± SD. Distance is recorded in meters (m). Time is recorded as seconds (s). Stroke count (SC) is recorded in number.

Table 2 (1:1 Work: Rest Ratio)

Distance	Control Time (s)	Pre-Plyo Time (s)	Mid-Plyo Time (s)	F-values	P-values
1^{st} 50 m	43.00 ± 2.67	43.33 ± 2.93	43.50 ± 3.44	.042	.959
1^{st} 100 m	89.23 ± 7.63	93.08 ± 9.19	92.32 ± 8.63	.344	.714
1^{st} 200 m	185.83 ± 17.71	193.18 ± 20.82	191.38 ± 20.97	.223	.803
2^{nd} 100 m	89.15 ± 9.09	94.10 ± 9.40	91.32 ± 7.75	.479	.628
2^{nd} 50 m	42.32 ± 3.99	43.98 ± 3.86	43.15 ± 3.16	.306	.741
SC 50 m	37.33 ± 5.35	37.83 ± 4.71	37.83 ± 4.26	.022	.979

Values are given as mean ± SD. Distance is recorded in meters (m). Time is recorded in seconds (s). Stroke count (SC) is recorded in number.

Table 3 (*Post-hoc* Test 1:2)

Protocol	T-Value	P-Value
Control vs. PrePlyo		
1st 50	0.950	.829
1st 100	-0.610	.985
1st 200	-3.760	.880
2nd 100	-2.280	.819
2nd 50	-0.600	.952
SC	-0.900	.927
Control vs. MidPlyo		
1st 50	-.950	.897
1st 100	-0.690	.981
1st 200	-2.270	.954
2nd 100	-0.020	1.00
2nd 50	0.720	.931
SC	-1.400	.927
PrePlyo vs. MidPlyo		
1st 50	-0.230	.989
1st 100	-0.080	1.00
1st 200	1.490	.980
2nd 100	2.260	.822
2nd 50	1.320	.788
SC	-0.500	.977

Table 4 (*Post-hoc* Test 1:2)

Protocol	T-Value	P-Value
<u>Control vs. PrePlyo</u>		
1st 50	-0.333	.980
1st 100	-3.850	.718
1st 200	-7.350	.801
2nd 100	-4.950	.602
2nd 50	-1.666	.719
SC	-0.500	.982
<u>Control vs. MidPlyo</u>		
1st 50	-0.500	.956
1st 100	-3.083	.807
1st 200	-5.550	.880
2nd 100	-2.166	.905
2nd 50	-0.833	.920
SC	-0.500	.982
<u>PrePlyo vs. MidPlyo</u>		
1st 50	-0.166	.995
1st 100	0.766	.987
1st 200	1.800	.987
2nd 100	2.783	.848
2nd 50	0.833	.920
SC	0.000	1.00

Discussion

The purpose of this study was twofold: 1) to determine the acute effect of land-based plyometric training on selected swim performance measures; and 2) to determine the acute effect of timing of plyometric exercise on selected swim performance measures when incorporating plyometric training into a single training session. No significant improvements were observed when acute lower body plyometric training (LBPT) was fused pre- or mid training session on selected swim performance measures. Therefore, the LBPT regimen did not influence acute swim performance measurements in the selected population utilized for this experiment.

It should be noted that the purpose of this study was not to indicate whether or not LBPT would improve competitive swim performance times, rather it was to determine the effects of LBPT on acute swim performance measurements during practice. The study was delimited this way because plyometric training would not be practical during swimming competition. Additionally, plyometrics have been shown to create a post-activation potentiation response that led us to hypothesize that the subjects would have been able to generate more force with each stroke following the plyometric exercises, and thus, finished the sets in less time. Therefore, each subject was instructed by the researchers to perform each individual event at an average practice pace intensity. While the fusion of LBPT did not have a positive impact on acute swim performance, it also showed no indications of creating fatigue as indicated by a lack of significant increase in swim times following the intervention.

Since the fusion of LBPT showed no indication of fatigue on swim performance measures within the first experiment of a 1:2 work-to-rest ratio, the incorporation of a secondary experiment was developed to determine if a decreased work-to-rest ratio time would induce fatigue. The second experiment involved a modified work:rest ratio, from 1:2 to 1:1. Comparable to the 1:2 protocol, the results for the 1:1 protocol indicated no improvements in acute swim performance, nor induced fatigue with the incorporation of Pre- or MidLBPT.

The data showed no indications of induced fatigue which can be inferred that the fusion of LBPT does not negatively affect acute swim performance measures either. With these results, the fusion of LBPT during practice cannot be discredited entirely. The results could also be viewed with the respect to the potential impact on the overall health of swimmers engaged in land based, weight-bearing activity in addition to swimming.

According to Boreham (2011), children and young adults who regularly participate in weight-bearing physical activities such as weight-lifting, body weight, or plyometric resistance training typically have stronger, healthier bones (Boreham, 2011). This participation in regular weight-bearing physical activity results in bone acquisition during adolescence leading to a greater peak bone mass and the reduced risks of developing osteoporosis later in life. However, those individuals who participate in regular non-weight-bearing activities such as swimming, cycling, and rowing during their adolescence years often have lower bone mineral densities (BMD) than their peers who do participate in weight-bearing activities (Scofield, 2012).

The incorporation of LBPT may not positively improve acute swim performance measurements, but the fusion of plyometric exercises into regular swim practice at the recreational level may improve bone mineral density in adolescent competitive swimmers at a critical time of growth and development without compromising the quality of the swim practice. Overall, the fusion of plyometric training into swim practice regimens did not negatively or positively affect acute swim performance in the participants involved. However, the long term effects of the incorporation of LBPT could have a positive effect on bone structure and health on adolescent individuals who participate in mostly non weight-bearing activities and sports.

The delimitations of this study could have been incorporated differently to gain the best possible results for this experiment. The post-activation potentiation response dictates that performing high-intensity, low-volume plyometric exercises immediately prior to another high-intensity, low volume effort (swim performance) should elicit improved performance in the latter effort. In this study, the swimmers participated in high-intensity, low-volume LBPT, but were then given ample time to recover rendering the potentiation response created from the plyometrics useless. Additionally, for the best possible outcome, the swimmers should have been performing the swim events at higher intensity than practice pace immediately after completing the plyometric regimen.

Future studies should examine the effects of swim performance measurements immediately following the fusion of LBPT protocols with high-intensity swim efforts, rather than having the participants recover. In this scenario, the post-activation potentiation response created from the land-based plyometric exercises can potentially manifest improvements in acute swim performance measurements.

Practical Applications

This study shows that the incorporation of LBPT could lead to greater BMD in swimmers who otherwise do not participate in weight-bearing activities. Competitive swimmers at the high school and collegiate level typically devote the majority of their practice time to long, non weight-bearing, endurance swim training. The incorporation of weight-bearing exercises in conjunction with swim practice is relatively rare and is why LBPT could be a positive cross-training activity for competitive swimmers during swim practice.

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