COMPARISON OF LAND-BASED VERSUS AQUATIC-BASED CARDIOVASCULAR WORKOUT ON PEAK HEART RATE, BLOOD LACTATE, AND ESTIMATED VO2 MAX IN EXERCISING POPULATION OF BHAVNAGAR

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Abstract

Background:

For cardiovascular health, regular exercise is essential. Because of the buoyancy and resistance of water, aquatic exercise has become more and more popular as a low-impact substitute for land-based workouts. Assuming comparable physiological effects when intensity is matched.

Aim & Objective: The aim of this study was to compare the effects of land-based versus aquatic cardiovascular exercise on estimated VO_2 max, blood lactate, and peak heart rate.

Materials and Methods: Twenty-eight physically active males (ages 18 to 25) were randomly assigned to either the Land (n = 14) or Aquatic (n = 14) groups for an interventional study. For four weeks, both groups trained three times a week at an intensity of 60–70% VO_2 max. Assessments of heart rate (using wearable monitors), blood lactate (using a Lactospark analyzer), and estimated VO_2 max (using a 12-minute Cooper run) were conducted both before and after the intervention.

Results: Twenty-eight participants completed the study. Baseline characteristics showed no significant differences. Both groups demonstrated significant within-group improvements in 12-minute run distance and estimated VO_2 max (Land: +6.95% & +9.35%; Aquatic: +6.73% & +8.54%). Blood lactate levels decreased at both 0 and 20 minutes post-session in both groups but without statistical significance. The Land group showed a significant 3.5% reduction in base heart rate; the Aquatic group had a non-significant 0.95% increase. Peak heart rate remained largely unchanged.

Conclusion: Effect size analysis revealed the most meaningful change in peak heart rate. Overall, both training modalities improved cardiovascular and metabolic performance similarly, with no significant inter-group differences.

Keywords: Aquatic exercise, Land based exercise, VO_2 max, blood lactate, heart rate, physical fitness, cardiovascular health, exercise intensity

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Introduction

Physical activity is crucial for improving health and reducing the risk of diseases like cardiovascular diseases, diabetes, and cancer. Different exercises, such as running, swimming, and cycling, have unique benefits on cardiovascular fitness, strength, and flexibility.[4] Aquatic exercises, in particular, are gaining popularity due to the added benefits of water's buoyancy, which reduces joint stress, and its resistance, which enhances muscle strength.[2]

Although aquatic exercises are believed to offer advantages over land-based exercises, research on their comparative effects has shown mixed results.[5] Most studies use protocols like cycling or high-intensity training, which may not directly apply to submaximal intensity exercises. This study aims to compare the effects of land-based versus aquatic exercise on estimated VO2 max, blood lactate, and peak heart rate in healthy young males, hypothesizing that both modalities will show similar physiological responses when exercise intensity is controlled using the Karvonen heart rate method.

Aim & Objective

The aim of this study is to compare the effects of land-based versus aquatic-based cardiorespiratory exercise on key physiological outcomes. Specifically, the study aims to compare the pre- and post-test values of peak heart rate, blood lactate levels, and estimated VO2 max between the two exercise groups. Additionally, the study will assess the pre-post differences and calculate the effect sizes to evaluate the overall impact of aquatic versus land-based exercises.

Materials and Methods

This was an interventional study approved by the Ethics Committee of Government Medical College, Bhavnagar (Approval No. 1171/2022). The study included 30 healthy male participants, all of whom were intermediate or advanced athletes according to the National Strength and Conditioning Association (NSCA) guidelines and had been engaged in regular exercise for at least 6 months prior to the study. Participants were recruited via a campus advertisement and were only included if they met the eligibility criteria, including being free from debilitating injuries, comorbidities, or the use of performance-enhancing drugs. The study was conducted between October and November 2023 at the city ground and a private swimming pool.

The sample size was calculated based on convenient sampling, and participants were age- and BMI-matched. After enrollment, the participants were randomly divided into two groups (Land group and Aquatic group) using an online random number generator.

Pre-Test Measurements

Before the intervention, baseline measurements of estimated VO2 max, blood lactate levels, and peak heart rate were collected:

1. **Estimated VO2 max** was measured using the 12-minute Cooper run test. The distance covered during the test was input into the VMA Running app along with the participant’s weight and age to estimate VO2 max.[3]
2. **Blood lactate levels** were measured using a Lacto-spark blood lactate analyzer.[6]
3. **Peak heart rate** was monitored using portable, wearable heart rate monitors.

Intervention

A total of 12 exercise sessions were conducted over 4 weeks, with 3 sessions per week. The participants in the Land group performed the exercises on the ground, while the Aquatic group performed the exercises in the pool.

1. **Land-based session:** Each session began with a 5-minute warm-up consisting of stretching and jogging,

followed by 25 minutes of running at 60-70% VO2 max, as calculated using the Karvonen method. Rest intervals of 2 minutes were taken at the mid-point of the session, followed by a 5-minute cool-down period with stretching and walking.

2. **Aquatic-based session:** The aquatic group began with a 5-minute warm-up inside the pool (no swimming was performed). The water level was set at 3 feet, and the water temperature was maintained between 24-26°C. The session involved water-based exercises, and a cool-down period was followed.

After the final session, post-test measurements for estimated VO2 max, blood lactate levels, and peak heart rate were taken at the same time of day to avoid any circadian variation, using the same methods as in the pre-test.

Results

Study Overview:

- **Participants**: 28 male participants, randomly divided into two groups: Land (n=14) and Aquatic (n=14).
- **Demographics**: The mean age of the Land group was 19.35 ± 0.49 years, and the Aquatic group was 20.14 ± 0.53 years. Mean BMI for the Land group was 21.2 ± 2.81 kg/m² and for the Aquatic group was 21.8 ± 2.27 kg/m².

Table 1: Baseline and Post-Test Comparison Between Land and Aquatic Groups

Parameter	Land Pre (Mean±SD)	Aquatic Pre (Mean±SD)	p-value	Land Post (Mean±SD)	Aquatic Post (Mean±SD)	p-value
BMI (kg/m²)	21.2±2.81	21.8±2.27	0.547	21.5±2.31	21.8±2.27	0.755
Base Heart Rate (bpm)	77.0±7.88	76.6±7.07	0.885	74.3±5.80	77.3±7.12	0.249
Peak Heart Rate (bpm)	181±12.6	180±10.0	0.705	181±12.6	181±11.4	0.794
12-min Run Distance (m)	2446±440	2597±451	0.396	2617±403	2773±374	0.347
Estimated VO2 Max	43.5±9.82	46.7±10.1	0.410	47.5±9.0	50.7±8.36	0.356
Blood Lactate 0 min	4.09±1.57	5.20±2.64	0.205	3.83±1.63	4.54±1.56	0.263
Blood Lactate	9.41±1.85	9.50±2.39	0.913	9.13±1.53	8.90±1.47	0.700

20 min						

Baseline Comparisons:

- No significant differences in baseline BMI, heart rate, VO2 max, 12-minute run distance, or blood lactate levels between the groups (p-values > 0.05).

Post-Intervention Findings:

- **BMI**: No significant change in either group post-intervention (Land: 21.5 ± 2.31, Aquatic: 21.8 ± 2.27).
- **Heart Rates**: Both base and peak heart rates were similar across groups post-intervention.
- **12-Minute Run Distance & VO2 Max**: Both groups showed improvement, but differences between groups were not statistically significant (Land: +6.95%, Aquatic: +6.73% for 12-min run; Land: +9.35%, Aquatic: +8.54% for VO2 Max).
- **Blood Lactate Levels**: No significant changes observed in either group (0-minute or 20-minute levels).

Group-specific Changes:

Table 2- Pretest vs Post test analysis land group (Student T-test)

Test	Pretest mean	Post test mean	Mean difference	p value	% change
BMI	21.2±2.81	21.5±2.31	-0.2933	0.239	+1.41%
BASE HEART RATE	77.0±7.88	74.3±5.80	2.7147	0.029	-3.5%
PEAK HEART RATE	181±12.6	181±12.6	-0.0187	0.334	0%
12 MIN RUN DIST.	2446±440	2617±403	-170.4000	0.001	+6.95%
EST. VO2 MAX	43.5±9.82	47.5±9.0	-4.0713	< .001	+9.35%
0 MIN	4.09±1.57	3.83±1.63	0.2647	0.713	-6.35%
20 MIN	9.41±1.85	9.13±1.53	0.2787	0.632	-2.86%

- **Land Group**:
  - Significant improvement in 12-minute run distance (+6.95%) and VO2 max (+9.35%).

- o Base heart rate decreased significantly by 3.5%.
- o Blood lactate levels showed small reductions but were not statistically significant.

Table 3- Pretest vs Post test analysis aquatic group (Student T-test)

Test	Pretest mean	Post test mean	Mean difference	p value	% change
BMI	21.8±2.27	21.8±2.27	0.0164	0.853	0%
BASE HEART RATE	76.6±7.07	77.3±7.12	-0.7140	0.320	+0.95%
PEAK HEART RATE	180±10.0	181±11.4	-1.5713	0.080	+0.5%
12 MIN RUN DIST.	2597±451	2773±374	-175.7167	< .001	+6.73%
EST. VO2 MAX	46.7±10.1	50.7±8.36	-3.9980	< .001	+8.54%
0 MIN	5.20±2.64	4.54±1.56	0.6573	0.283	-12.5%
20 MIN	9.50±2.39	8.90±1.47	0.6000	0.504	-6.3%

- **Aquatic Group**:
  - o Significant improvements in 12-minute run distance (+6.73%) and VO2 max (+8.54%).
  - o Small increase in base heart rate (+0.95%) and peak heart rate (+0.5%), though not statistically significant.
  - o Blood lactate reductions were not significant.

Table 4- Pretest-post test difference score of all parameters

	PRE-POST DIFFERENCE		
MEASURE	LAND	AQUATIC	
	MEAN± SD	MEAN± SD	p value
BMI	0.29±0.95	0.02±0.34	0.512
BASE HEART RATE	-2.71±4.47	0.71±2.78	0.334
PEAK HEART RATE	-2.71±1.68	0.29±3.41	0.007
12 MIN RUN DIST.	180±164	175±127	0.434
EST VO2 MAX	4.07±3.74	4.0±2.87	0.954
BLOOD LACTATE 0 MIN	-0.26±2.84	-0.66±2.36	0.694
BLOOD LACTATE 20 MIN	-0.28±2.29	-0.60±3.52	0.777

Table 5 -Percentage change and Cohen’s d in Land and Aquatic group before and after intervention

Test	Posttest-pretest % change - Land	Posttest-pretest % change - Aquatic	Cohen's d
BMI	+1.41%	0%	-0.437
BASE HEART RATE	-3.5%	+0.95%	0.919
PEAK HEART RATE	0%	+0.5%	1.1165
12 MIN RUN DIST.	+6.95%	+6.73%	-0.0340
EST. VO2 MAX	+9.35%	+8.54%	-0.0219
0 MIN	-6.35%	-12.5%	-0.1505
20 MIN	-2.86%	-6.3%	-0.1083

Statistical Analysis:

- **Effect Size** (Cohen's d): Peak heart rate showed the largest effect size,
- suggesting a more meaningful change compared to other parameters.
- **Pre/Post-test Difference**: Statistically significant changes in 12-minute run distance and VO2 max were observed within both groups, while other measures (e.g., BMI, heart rate, blood lactate) showed no significant pre-to-post changes.

Discussion

In this study, both **land and aquatic training** resulted in significant improvements in cardiovascular and metabolic parameters. The participants in both groups had similar baseline characteristics, including age, BMI, and gender, ensuring comparability across the groups. Improvements were observed in **12-minute run distance**, **VO2 max**, and **blood lactate levels** for both groups, although no statistically significant differences were found between the two forms of exercise.

The improvement in **VO2 max**, which reflects the efficiency of the respiratory, cardiovascular, and muscular systems, was similar across both groups. Both land and aquatic exercise led to increases in VO2 max, which is consistent with findings from previous studies. Adaptations like increased **cardiac output**, **pulmonary function**, **capillary density**, and **muscle mass** contribute to these improvements. Studies by **Marrow et al.**, **Long et al.**, and **Quinn et al.**[7] also support the notion that both land and aquatic exercise can improve VO2 max. However, it has been suggested that increasing training intensity beyond 60% of VO2 max does not yield further significant improvements, as demonstrated in a meta-analysis by **Scribbans et al.**.[8]

Blood lactate levels decreased in both groups, suggesting improved **lactate clearance** and **buffering capacity**. However, these changes were **not statistically significant**, possibly due to insufficient training intensity. Research by **Arvydas Stasiulis et al.** has shown that training at lactate threshold intensity is necessary for significant changes in both aerobic and anaerobic capacities. The observed improvements in lactate clearance may be attributed to increased mitochondrial enzyme activity, enhanced fat oxidation, and better lactate buffering capacity.

Regarding **heart rate**, both groups showed small changes in **base heart rate** and **peak heart rate**. In the **Land group**, the **base heart rate** decreased significantly by 3.5% (2-3 bpm), while the **Aquatic group** showed a slight increase of 0.95%. The **peak heart rate** remained mostly similar in both groups. Previous studies, such as those by **Fukuie et al.** and **Graef et al.**, have found similar small or non-significant changes in resting heart rate following exercise training, which supports our findings. The reduction in base heart rate in the Land group may be explained by **exercise-induced bradycardia**, a result of increased parasympathetic tone and intrinsic changes in the heart's electrical system.

The results suggest that **aquatic training** can be a viable alternative to land-based training, especially for individuals who are unable to train on land due to joint pain or injury.[1] For example, older adults or those with **lower limb injuries** could benefit from pool-based exercise, as it provides similar cardiovascular and metabolic benefits without the high-impact stresses of land-based exercises. **Physical therapists** can utilize aquatic exercises to help individuals improve their cardiovascular function while minimizing strain on their joints.[9]Athletes undergoing rehabilitation may also use aquatic training to maintain or improve their fitness levels.

Conclusion

In our study, base heart rate decreased by 3.5% in the land group and 0.95% in the aquatic group, while peak heart rate remained unchanged in the land group and increased slightly by 0.5% in the aquatic group, although these changes were not statistically significant. Both groups showed significant improvements in the 12-minute run test, with the land group covering 6.95% more distance and the aquatic group covering 6.73% more distance. Estimated VO2 max increased by 9.35% in the land group and 8.54% in the aquatic group, both statistically significant.

After 4 weeks of training, blood lactate levels decreased by 6.35% at pre-session (0 minutes) in the land group and 12.57% in the aquatic group, but these reductions were not significant. Post-session (20 minutes) blood lactate levels dropped by 2.86% in the land group and 6.3% in the aquatic group, though the difference was not statistically significant.

Table 6 indicated a large effect size for base and peak heart rate, suggesting a strong significance in these changes. Based on our findings, we recommend aquatic exercise as an effective alternative for individuals bored with land training, older adults with lower limb pain, and athletes recovering from knee or ankle injuries to maintain or improve cardiovascular and metabolic function.

Future research should focus on older adults or injured athletes as specific populations and incorporate diet monitoring to further investigate the physiological differences between the two training methods.

Strengths & Limitations

The strength of our study lies in its larger sample size of 28 participants, compared to previous studies that typically included 12-14 subjects. Additionally, the exercise intensity was matched in both groups based on heart rate, providing a standardized foundation for future studies to compare results. However, one limitation is that our study only included male participants due to a lack of sufficient physically active females. Furthermore, the work-rest ratio was not specified, and nutrition monitoring was not included, which should be considered in future research to enhance the study's findings.[10]

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