Review Paper

Aquatic exercise blood lactate levels compared with land based exercise blood lactate levels

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ABSTRACT

Water based exercise is a popular medium for exercise for a number of populations from athletic to elderly to post orthopaedic. Many of the physiological variables have been studied on the benefits of aquatic exercise such as reduction in impact, range of motion and heart rate response. One area which has been overlooked is blood lactate (BLac) response to exercise in water. Exercise in water may elicit different physiological responses to blood lactate levels. If the objective is to improve a client's exercise tolerance, then understanding the physiological difference to exercise in water will enable the clinician/coach to formulate appropriate interventions to enable to use this medium to the benefit of a patient and or an athlete. This study is a systematic review of peer-reviewed papers, which have compared BLac levels during aquatic exercise and land based exercise. A systematic search on a number of peer reviewed search engines resulted in 13 studies. **Key words:** AQUATIC THERAPY, EXERCISE & BLOOD LACTATE.

Cite this article as:
Payton, S. (2018). Aquatic exercise blood lactate levels compared with land based exercise blood lactate levels. *Journal of Human Sport and Exercise, 13*(3), 659-666. doi:https://doi.org/10.14198/jhse.2018.133.16

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Submitted for publication February 2018
Accepted for publication April 2018
Published *in press* May 2018
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2018.133.16

METHOD

The author chose papers using a combination of Boolean logic and key words or phrase using the following words aquatic, land, hydro, water, lactate and exercise across four peer reviewed research search engines: Sport discus, PubMed, Scopus and Springer. This brought up 586 papers; after manually checking titles for relevance 46 papers where looked at further depth. After further reading 13 papers were left to review.

INTRODUCTION THE PHYSIOLOGICAL EFFECTS OF IMMERSION

There is an increase in the number of people taking part in water-based activities whether it be the healthy population taking part in aqua aerobics or the disability population for specific rehabilitation. More recently, the benefits and physiological responses to aquatic exercise have been studied. There is a growing understanding of the physiological responses to exercise in water compared to land based exercise. A number of different physiological responses to exercise in water have been studied such as reduced impact on lower limb joints (Robinson 2004) (1) , heart rate response Shono et al (2001) (2) (Becker)(2009) (3) , Adelaida María Castro-Sánchez, (2012) (4) & Häkkinen A (2007) (5) , changes in lung function Chu (2002) (6), renal output Norsk (1990) (7) , cathelamine responses RD Benfield (2010) (8) , pain Walker (2009) (9), RPE Wilder et al (1993) (10) and swelling Hinman (2007) (11). However, there is still areas where physiological responses to exercise in water has received less coverage. This paper will focus on blood lactate levels. Low levels of blood lactate during exercise would be of benefit for many populations from athletic to special such as COPD were patients generally have low exercise tolerance due to the damage in their lungs. This paper will review and will compare the physiological responses to blood lactate during emersion and similarly activity on land.

BLOOD lactate

It is important to appreciate the physiological responses that result in changes in blood lactate before discussing the topic any further.

Lactic acid builds up during exercise. At high levels, it can produce pain and limit performance due to a build-up of hydrogen ions. Maintaining a low blood lactate level will delay the onset of blood lactate accumulation (OBLA) which would have many benefits for improving exercise tolerance of trained athletes and in special populations such as patients with chronic obstructive pulmonary disease (COPD) n. Studies by Casaburi (1989) (12) conclude that most COPD subjects studied increased blood lactate at low work rates. Due to the damage to their lungs, COPD patients generally have low exercise tolerance. COPD is projected to become a major health problem by 2020 with a third of leading cause of death and fifth leading cause of disability Raherison (2009)(13). An exercise environment to improve patient exercise tolerance would be beneficial.

Pulmonary ventilation removes Co2 in general population. In COPD population there is an increase in Co2 due to the damage to the lungs. This increase in Co2 then combines with water resulting in formation on carbonic acid. The carbonic acid releases the hydrogen ions (H+) . This results in abnormal level of H ions resulting in hypercapnic acidosis N.Madias (1982) (14). The insufficiency of oxygen to remove H+ will make the muscle cells acidic and interfere with electron carrier molecules nicotinamide adenine dinucleotide (NADH). The NADH donate electrons by providing a hydrogen molecule to the oxygen molecule to create water during the electron transport chain. With insufficient oxygen supply then NAD+ cannot release the H+ and they build up in the cell. To prevent the rise in acidity pyruvic acid accepts H+ forming lactic acid that then dissociates into lactate and H+. Some of the lactate diffuses into the blood stream and takes some H+ with it as a way of reducing the H+ concentration in the muscle cell. The increase in hydrogen ions as a result of increased physical activity results in a lowering of the pH in the muscles from 7.1. Once pH reaches the level of 6.5 then muscle contraction becomes impaired. Furthermore the low pH will stimulate the free nerve endings in the muscle resulting in the perception of pain. These same principles will apply to an athlete where the onset on an increase in blood lactate will inhibited their ability to continue to train.

Modes of aquatic exercise

This review paper will cover different modes of aquatic exercise: deep water running (DWR), shallow water running (SWR), water immersion cycling (WIC) and aqua aerobics (AA). The DWR is conducted without touching the bottom of the pool and with the aid of a specially designed floatation belt. SWR is either conducted on a submerged treadmill or running horizontally lengths of the pool. AA is conducted in partial weight bearing in the shallow side of the pool. Finally cycling is conducted in the shallow side of the pool on a static bike. This review paper will focus on blood lactate response to aquatic exercise at various exercise intensities.

BLOOD LACTATE PHYSIOLOGICAL RESPONSES TO EXERCISE IN WATER

Physiological response maximal exercise in deep water

Glass (1995) (15) and Svedenhag (1992) (16) found deep-water running (DWR) at maximal intensity would produce higher BLac compared to land based treadmill running. Town (1991) (17) and Nakanishi (1999) (18) found maximal DWR to produce lower BLac than land based treadmill running. 19. Rutledge (2007) (19) , Chu (2002) (20) , Frangolias (1995) (21) and Silvers (2014) (22) report finding no significant difference in BLac levels when comparing treadmill running on land and during water immersion. Glass (15) and Svedenhag (16) suggests the higher BLac levels are due to greater reliance on anaerobic metabolism due to the redistribution of blood from lower limbs to central portion of the body due to hydro static pressure . Furthermore they hypothesis that the changes in muscle activation patterns reported by Silvers (2014) (22) have an effect on the Blac levels.

Looking at Silvers (2014) (22) and Frangolias (1995) (21) studies in isolation, all participants were trained runners who may well be use to undertaking DWR and therefore be conditioned to DWR and elicit the same physiological responses on land as in water, which is comparable to findings reported by Becker (2009) (23) where he found no physiological difference between aquatic and land medium. The findings by the other authors Town (1991) (17) and Nakanishi (1999) (18) where they recorded lower BLac levels could result of lower plasma epinephrine concentrations as a result in reduced sympathoadrenal response at high intensity exercise Connelly (1990) (24).

Physiological response maximal cycling exercise in water

Only one study has so far has looked at maximum cycling in water and on land. Yazigi (2013) (25) determining lower BLac at maximal WI cycling compared to land based cycling. This paper suggests lower BLac levels in water due to enhanced blood flow back to the heart as a result of hydro static pressure.

Physiological response maximal exercise in shallow water

When looking at partial weight bearing exercise at maximal intensity Cook (2013) (26) found BLac levels to be higher during SWR compared to land based. Cook study was conducted by running lengths of the pool. Cook recording near double BLac levels in the water based exercise compared to the land based. Two possible reason for such a contrast in this study. One the duration of the exercise running 9.1 meter ten times in water will take sufficiently longer than running 9.1 meters on land. Resulting in the participants utilising differing energy systems. Furthermore cutting through the water rather than staying a stationarity position such as in tethered aqua jogging or underwater treadmill running results in much greater displacement of water resulting in increased load on the musculoskeletal system.

Physiological response in low intensity exercise shallow water

Kang et al (2014) (27) and Benelli (2004) (28) both conducted moderate to low intensity exercise in shallow water Kang walking and Benelli aqua aerobics. Both of these studies recorded lower blood lactate levels in the water based exercise compared to the land based exercise. At low intensity exercise the buoyancy of the water and the hydro static pressure a likely reasons why BLac levels are lower in water compared to land based exercise.

Table 1. Blood Lactate Physiological responses to exercise.

Study	**Year**	**Total**	**Exercise**	**Blac**	**Blac**
				WI	Land
Glass	1987	10	DWR	14.9	11.2
Town Bradley	1991	9	DWR	6.4	7.9
Svedenhag	1992	9	DWR	12.4	10
Frangolias	1995	13	DWR	9.8	10.4
Glass	1995	20	DWR	15.2	11.8
Nakanishi et al.	1999	14	DWR	9.2	13.8
Nakanishi et al.	1999	20	DWR	10.44	12.47
Frangolias	2000	10	DWR	9.7	10.7
Chu	2002	9	DWR	8.62	8.99
Benelli	2004	8	Aerobics	1.75	5.65
Silver	2007	23	Treadmill	12.2	12.1
Cook	2013	20	Shallow water sprinting	8.08	4.13
Yazigi	2013	10	Cycling	11.9	14.9

DISCUSSION

In summary, the following reasons have been given from the above papers. High intensity DWR higher BLac due to blood volume redistribution, changes in muscle activation and poor running mechanics, high intensity DWR lower BLac due to lower plasma epinephrine concentrations as a result of reduced sympathoadrenal response. High intensity static cycling lower BLac due to enhanced blood flow due to hydrostatic pressure. High intensity shallow water running produced higher BLac compared to running on land this is most likely due to length of time to complete the protocol 15 seconds in water and 1.8 seconds on land per 9.1m. There has been a number of conflicting results on BLac levels when comparing water based exercise to land based exercise this is due to a wide variety of issues regarding participants, poor methodology control, differing intensities and different exercise protocols to draw any firm conclusion on whether exercise in water produces any variation in blood lactic levels compared to land based exercise. With this in mind, where does that leave us?

There are a number of physiological properties of water that are only briefly touched upon in the above papers. These properties have a profound effect upon the immersed human body.

Water exerts pressure which is proportional 1mm Hg per 1.36cm at a depth at 121cm the pressure is at 89 mmHg which is higher than normal diastolic blood pressure of 80mm Hg at this depth blood is facilitated back to the heart which results in a drop in resting heart rate.

Water has the effect of reducing loading on the human body due to buoyancy, which creates upward thrust an increase in depth of water there is an increase upward thrust and a decrease in impact on the joints. Immersion to the pubis symphysis results in an offloaded of 50%. Water density is 829 higher than air at 30 degrees Lide (1990). The temperature the majority of the research was conducted at 30 degrees just below thermal neutral temperature, a higher temperature will lead to adverse physiological effects due to the intensity of the exercise.

The viscosity of water acts as a resistive force called drag force under turbulent flow resistance increases as a log to the function of velocity. The power and strength to overcome drag force under turbulent conditions is actually the cube of the velocity therefore doubling the speed of movement requires 8 times the power. This physical difference compared to land based exercise results in participants who have a lower power output very difficult if not impossible for to perform movements at maximal speed which would illicit the same physiological response as an athlete with greater power out thus one participants maximal intensity would result requiring a different energy system than another athlete when performing extended DWR. This may account for the trained runners able to elicit same blood lactate levels in the water as on land. Water can only displace so quickly as you displace the water, it's going to be pushing against nearby water and creating some pressure which is going to push back against the displacing water (water doesn't like to be compressed, so it can't just decrease its volume like a gas can such as on land). The more water you attempt to displace and the less time you give it to adjust such as increasing the speed of movement, the greater the force you will need to apply. The cut off from water acting as facilitator of movement rather than a resistive force occurs around 70 degrees per second. L brody (2009) (29) . If one participants maximal speed of movement is below 70 degrees per second then they will always have the water acting a facilitator of movement (buoyancy). These properties of water give as an indication of why there are so many conflicting results in BLac readings. At slow movements water facilitates movements in a upwards direction through buoyancy resulting in less active muscle recruitment and aids blood back to the heart through hydrostatic pressure. We can assume in the low intensity exercise all the participants movements were below 70 degrees per second resulting in the water acting as a facilitator of movement and aiding venus return these physical property can support why at low intensity exercise in the water can record lower blood lactate levels than from a land-based exercise at the same intensity such as and Benelli 2004 (28) paper . At higher intensity exercise in water acts as a resistive force resulting in much higher physical effort which would support Glass (1995) (15), Svedenhag (1992) (16) and Cook (2013) (26) findings of higher BLac levels. Although the findings of the two other papers Town (1991) (17) and Nakanishi (1999) (18) find lower BLac levels; the speed of the movement can still account for these results. The participants may well lack the strength/power to result in an increased velocity and or the running technique was such that angular velocity was not sufficiently high enough to result in the water to act as resistive force resulting the BLac levels below that of land based level. The Silvers (2007) (22) and Frangolias (1995) (21) studies both found no difference between water or land protocols as again no reported angular velocities are reported it may well be that the participants were not moving their limbs through the water at such as speed that water was not acting as a resistive medium . Furthermore the participants in these studies were trained athletes who are possibly conditioned to aquatic DWR. Water temperature is not reported in all the studies it is unlikely the temperature was the same for all the studies so this will have an effect on comparing one study to the next as water has a heat capacity 1000 times greater than air and is 25 times faster at conducting heat than air. Water temperature between 26 - 29.5 degrees centigrade is reported to be best for vigorous exercise Becker (2009) (3). Temperatures above 33 degrees have been reported to have increased heat load resulting in changes in circulation.

CONCLUSION

Conflicting results on BLac levels when comparing water based exercise to land based exercise can be due to a lack of strict criteria and methodical procedures. Where does that leave us? The one area where articles support each other is that low intensity exercise in shallow water produces lower Blac levels than compared to land based exercise. This evidence highlights the possibility that aquatic exercise could be a useful medium to improve OBLA for a variety of populations. Further studies in high intensity exercise are required with strict criteria on water temperature, speed of movement of limbs through the water and participant demographics to conclusively determine what if any differences there are in BLac levels in aquatic exercise vs land based exercise.

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