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Effect of yoga on blood lactate in sportsperson: A meta-analysis

Chitra Chand[1], Dhananjoy Shaw[2]
[1] PhD Student, Department of Yoga Science, University of Patanjali, Haridwar, Uttarakhand, India
[2] Principal (Officiating), Indira Gandhi Institute of Physical Education and Sports Sciences, University of Delhi, New Delhi, India

Abstract
Blood lactate (La) is a vital parameter to evaluate the post exercise recovery from physiological fatigue in sportsperson. Yoga is a low to moderate intensity active recovery mode that may enhance the La recovery and production capacity or anaerobic capacity. This review aims to put forth the findings available on effectiveness of yoga training on La removal and to analyze the studies in regard to gender and age. The electronic databases such as PubMed, Science Direct, Wiley Online Library and Google Scholar were searched from 2000 to 2020 using the keywords 'blood lactate', 'yoga', and 'athletes'. 12 studies were retrieved for critical analysis. From the findings it was concluded that yoga practice reduces La thereby, improving work rate, anaerobic threshold, reducing muscle fatigue, stress reactivity that results in low exertion on the individuals as compared to other physical activities. The duration of yoga intervention to observe reduction in La may range from five to thirty minutes for acute effect and six weeks to two years for chronic effect. However, there was no gender difference in regard to yoga practice and reduction of La concentration as well as there is lack of sufficient literature to explain the effect of yoga practice on La in regard to age.

Keywords: Blood lactate, yoga, athletes, recovery.

Introduction
Blood lactate (La) is a vital parameter to evaluate the post exercise recovery from physiological fatigue in sportsperson. High level of La indicates ischemia or it can be a normal response to physiological exertion (Goodwin *et al*., 2007) [7]. The La concentration is a resultant of lactate production and disappearance in the skeletal muscles. (Ghosh, 2004; Sharma *et al*., 2017) [6, 13]. The normal range of La at rest for a healthy person is 0.5 to 1 millimoles per liter (mM/L) (Schnur, 2017).

While performing endurance exercises the La level increases gradually at the initial stage and then rapidly as the intensity of the exercise increases (Goodwin *et al*., 2007) [7]. The initial elevation of La depicts that the appearance rate of lactate in blood is greater than the clearance rate. The exercise intensity at which there is a sudden accelerated increase (the fluctuation point) in La level is called 'lactate threshold' of the individual. When the La reaches 4 mM/L it is referred to as 'Onset of Blood Lactate Accumulation or OBLA' (Ghosh, 2007). During low and moderate intensity exercises the La concentration ranges from 1 mM/L to 2 mM/L ("Lactate Measurement", n.d.). In submaximal or maximal exercises lasting 30 to 120 seconds, the peak La values of ≈15 to 25 mM/L may be observed 3 to 8 minutes post exercise (Goodwin *et al*., 2007) [7]. The recovery time for La to return to basal level from peak values may range from 30 to 60 minutes (Sharma *et al*., 2017) [13]. High level of La (>8 to 10 mM/L) is a limiting factor for physiological performance capacity of an individual (Solberg *et al.*, 2000) [14].

Blood Lactate is also considered a better predictor of performance than VO_{2max} and a better indicator of exercise intensity than Heart Rate (Goodwin *et al*., 2007) [7]. Many studies in the past have used various modes of recovery such as compression garments, electrostimulation, passive recovery, active recovery and many more (Sharma *et al*., 2017) [13]. Yoga is a low to moderate intensity active recovery mode that may enhance the La recovery and lactate production capacity or anaerobic capacity (Solberg *et al*., 2007; Benavides-Pinzon & Torres, 2017; Coco *et al*., 2020) [5]. This review aims to put forth the findings available on effectiveness of yoga training on blood lactate and to analyze the studies in regard to gender and age.

Materials and methods:
The electronic databases such as PubMed, Science Direct, Wiley Online Library, Google Scholar were searched from 2000 to 2020 using the keywords "blood lactate"; "yoga"; and "athletes". The studies conducted on healthy human participants were included. They were not restricted on the basis of gender, age and ethnicity of the subjects. The studies where subjects had any pathological or psychological conditions such as diabetes, stroke, depression, etc. were excluded. The meta-analysis included the studies that were conducted from the year 2000 up until now with the exception of two research articles [Raju *et al*., (1994) [11] and Raju *et al*., (1986)] [10] and a conference abstract [Pazare and Biswas (2011)] because of their high citation index score and relevance to the concerned meta-analysis respectively. The selection process of included articles is explained in Fig. 1.

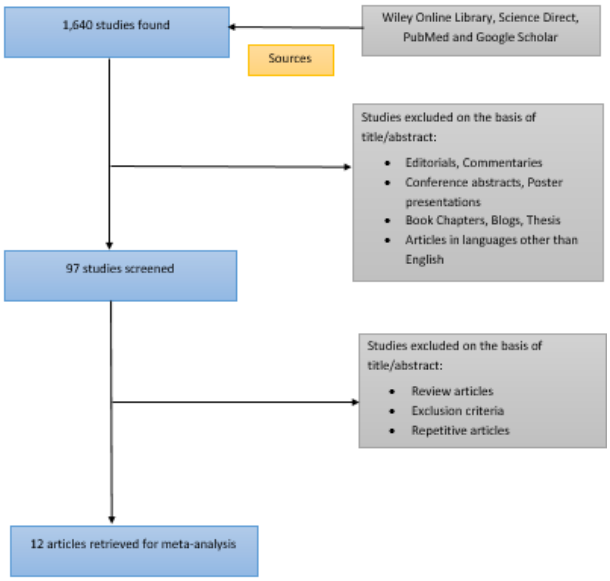

Fig 1: Flow Chart Explaining the Selection Process of Studies Included in Meta-Analysis

Results

Effect of Yoga Training on Blood Lactate in Sportsperson or Healthy Individuals

Table 1: Summary of Studies Depicting the Effect of Yoga Training on Blood Lactate in Sportsperson or Healthy People

S.No.	Study	Experimental design	Intervention	Duration	Result	Conclusion	Remarks
1.	Raju *et al*., (1986) [10]	Longitudinal	Yogasana and pranayama	20days-Phase I 90 days-Phase II	a) Decreased La in males in Phase II. b) Increased La in females in Baseline and Phase I.	a) Reduced La after longer practices of yoga. b) Increase in aerobic and anaerobic threshold that resists fatigue.	a) No control group. b) Small sample size.
2.	Raju *et al*., (1994) [11]	Longitudinal	Pranayama and shavasana	1 year-Phase I 2 years-Phase II	Reduced La in phase I and II at rest.	a) Pranayama increases work rates with reduced oxygen consumption per unit work, without increase in blood lactate levels. b) Pranayama improves performance of athletes. c) Better oxygen delivery and improved oxygen utilization due to improved cellular respiration.	a) Only male subjects. b) Small sample size
3.	Solberg *et al*., (2000) [14]	Prospective Cohort	Meditation vs. autogenic training	6 months	Reduced La in-meditation group.	Meditation training may reduce the lactate response to a standardized exercise bout.	a) Delimited to male athletes. b) Only relaxation techniques were considered.
4.	Prasad *et al*., (2001)	Short-term longitudinal	Nadishodhana pranayama vs. treadmill walking vs. field walking	30 minutes each	Decreased La after nadishodhana pranayama.	Reduced La indicate low exertion on the subjects during nadishodhan than in other forms of physical exercises.	a) Subjects were those who practiced yoga for >3 years. b) Subjects were males. c) Small sample size.
5.	Bucheit *et al*., (2009)	Short-term longitudinal	Upright vs. sitting vs. supine vs. supine with legs up	5 minutes	No position or position × condition interaction effect.	No position effect was seen on La levels.	a) Subjects did not practiced yoga. b) Yoga was not given as intervention. c) Small sample size.
6.	Pazare and Biswas (2011)	Longitudinal	Rajyoga meditation	8 weeks	Lower La level.	Decrease in lactate level reduces the degree of muscle fatigue and improves muscle	a) No control group. b) Small sample size.

						performance.	
7.	Pazare *et al*., (2013)	Longitudinal	Rajyoga meditation	6 months	Reduced La level	a) Rajyoga meditation improves performance in badminton players. b) It may reduce stress reactivity as measured by decreased lactate response.	a) No control group. b) Small sample size.
8.	Beutler *et al*., (2016) [2]	Cross sectional	Yogasana and pranayama	Not Applicable	Insignificant difference between yoga and control group after first eight minutes of incremental cycling and constant - load exercise test.	Yoga practice does not improve exercise capacity and exercise ventilation despite significant difference in respiratory regulation at rest and in response to hypercapnia and passive leg movement.	a) Subjects were those who practiced yoga for past 8.1±6.6 years. b) Subjects were females. c) Small sample size.
9.	Benavides-Pinzon and Torres (2017)	Quasi experimental	Pranayama	12 weeks	Post pranayama La was more than 45 minutes exercise on cycle ergometer at 75% maximum heart rate.	a) Pranayama practice for 12 weeks improved lactate capacity (anaerobic capacity). b) It can help in improving cardio-respiratory functions.	a) No randomization. b) Unequal sample distribution.
10.	Bizjak *et al*., (2019)	Longitudinal study	Endurance training	6 weeks	La decreased at exhaustion.	a) Aerobic capacity and ventilatory threshold and velocity at lactate threshold improved. b) Improved performance.	a) Subjects practiced non endurance activities- combat sports, horse riding and yoga. b) Yoga not given as intervention.
11.	Wooten *et al*., (2020)	Randomized crossover	Yogasana	2 hours for 2 days	Increased La level for blood flow restriction (BFR) band and non-BFR band.	Blood lactate level was higher after performing yoga with BFR bands.	a) Self as control. b) Novice yoga practitioners as subjects. c) BFR bands used.
12.	Coco *et al*., (2020)	Pilot study	Ashtanga vinyasa yoga	Not Applicable	a) Possible correlation among La and number of years of yoga and gym practice at rest. b) Negative linear correlation between La and number of years of yoga practice at rest and end of session.	Significant difference in blood lactate level at rest and number of years of yoga or gym practice in the study group or control group.	a) Subjects were those who practiced yoga (Study) and gym (Control) from past 1-34 years and 1-14 years respectively. b) No intervention given.

Effect of Yoga Training on Blood Lactate in Regard to Gender and Age

Table 2: Summary of Sample Statistics Included in Meta-Analysis in Regard to Gender and Age Differences

S. No.	Study	Study Population	Sample Size	Gender	Mean Age ± SD (in years)
1.	Raju *et al*., (1986) [10]	Healthy volunteers	12	Female and male	21.50 ± 2.51 (F) 25.83 ± 2.64 (M)
2.	Raju *et al*., (1994) [11]	Sportsmen	16-Phase I 12-Phase II	Male	18.69 ± 1.00 (P-I) 17.00 ± 3.05 (P-II)
3.	Solberg *et al*., (2000)	Marathon runners	31	Male	39 ± 7
4.	Prasad *et al*., (2001)	Yoga practitioners	12	Male	27.1 ± 10.7
5.	Bucheit *et al*., (2009)	Moderately trained individuals	11	Male	22.1 ± 3.0
6.	Pazare and Biswas (2011)	Badminton players	30	Not given	Not given
7.	Pazare, Biswas and Meshram (2013)	Badminton players	35	Male	18 ± 3
8.	Beutler *et al*., (2016) [2]	Yoga practitioners	15	Female	36 ± 6
9.	Benavides-Pinzon and Torres (2017)	Sedentary individuals	103	Female and male	46 ± 14.3
10.	Bizjak *et al*., (2019)	Healthy individuals	31	Female and male	23. 9 ± 3.3
11.	Wooten, Stray-Gundersen and Tanaka (2020)	Healthy individuals	20	Female and male	23 ± 4
12.	Coco *et al*., (2020)	Yoga and gym practitioners	54	Female	55.07 ± 5.43

F= female, M= male, P-I= Phase I, P-II= Phase II.

Discussion

Yoga intervention is very popular for controlling blood lactate level by and large with few exceptions. A good number of studies on sportspersons in regard to effect of yoga practice on blood lactate concentration are readily available. It was observed that over 30% studies consisted of yogasana and pranayama and 30% meditation as an intervention. The yoga protocol by and large in these studies has been listed in the following order: shavasana* for five to twelve minutes, meditation for thirty to sixty minutes, nadishodhana pranayama for two to thirty minutes and kapalabhati not specified in regard to duration of practice. The duration of intervention for observing the acute effect range from five minutes to thirty minutes. The duration of intervention for observing the chronic effect (adaption effect) range from six weeks to two years.

Approximately 45% of the studies under consideration were performed on male subjects and 35% studies on subjects from both genders. Very few studies have been conducted on females, Beutler *et al*., (2016) [2] concluded that due to constant hormonal and thereby physiologic changes that may affect the results. A study observed no significant reduction in blood lactate in females in comparison to males after 90 days of yoga training (Raju *et al*., 1986) [10]. Other studies included in the meta-analysis do not allow gender comparison due to unequal sample size or lack of data. Previous studies involving active recovery as an intervention on male and female subjects of similar physical fitness have also explained that there exists no difference in lactate accumulation and removal with respect to gender (Zhang and Ji, 2016).

This meta-analysis includes studies that were conducted on young adults (age ranging between 17 to 36 years) and middle-aged adults (age ranging between 37 to 55 years). Though only one study analyzed and depicted that there exists no significant relation between blood lactate concentration and age, but it did not explain the reason. However, the same study illustrated that lactate levels are reduced with the number of years of yoga practice (Coco *et al*., 2020) [5]. None of the other studies pointed out any relation between age and lactate concentration. However, existing literature reflects that endurance performance is reduced during middle-age and declines at an even rapid rate in older age and a decrease in lactate threshold is a contributing factor (Tanaka and Seals, 2008).

*****Note- Bucheit *et al*., (2009) included supine lying posture which may be considered as shavasana.

Conclusions

This meta-analysis can be concluded in the following points:

1. Yoga practice reduces blood lactate concentration thereby, improving work rate, anaerobic threshold, reducing muscle fatigue, stress reactivity that results in low exertion on the individuals as compared to other physical activities.
2. The duration of yoga intervention to observe reduction in blood lactate concentration may range from five to thirty minutes for acute effect and six weeks to two years for chronic effect.
3. There is no gender difference in regard to yoga practice and blood lactate concentration.
4. A lack of sufficient literature to explain the effect of yoga practice on blood lactate levels in regard to age.

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