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RESEARCH ARTICLE

A study on change in ejection fraction during simulated diving in humans

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ABSTRACT

Background: It has been observed that complex cardiovascular changes including cardiac rhythm and conduction occur during simulated diving in humans. As the study requires technical expertise, not many studies are conducted in this field. Two-dimensional (2D) echocardiography is a feasible method to study the cardiovascular changes during breath-hold immersion of the face in water. There is well-documented evidence for changes in left ventricular (LV) end-diastolic volume, stroke volume, and cardiac output. LV ejection fraction (LV EF) which is an important cardiac parameter that determines the amount of oxygenated blood each organ receives has not gained much attention. Hence, the present study was focused on the changes in LV EF with breath-hold immersion of the face in water. **Aims and Objective:** The objective of the study is to observe the change in LV EF during breath-hold immersion of the face in water using 2D echocardiography. **Materials and Methods:** The study was conducted in 15 male swimmers of age group 25–35 years, who are used to active breath-hold swimming. **Results:** There was a statistically significant reduction in LV EF during breath-hold immersion of the face in water. **Conclusion:** Cardiovascular changes during breath-hold immersion of the face in water are important as a majority of our population is involved with water-related activities for leisure, sports, or livelihood. The change in the cardiac parameter, LV EF, can be extrapolated to the case of actual swimming.

KEY WORDS: Simulated Diving; Ejection Fraction; Breath-Hold Immersion; Echocardiograph

INTRODUCTION

Diving reflex includes various mechanisms mainly concerned with oxygen conservation.[1] It is observed that complex cardiovascular changes occur during simulated diving in humans. In the previous studies, it is noted that changes including cardiac rhythm and conduction are common during simulated diving.[2]

Bradycardia is a noted feature in those who do underwater diving as well as during breath-hold wetting of the face. This response has been attributed to a high resting vagal tone.[3]

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Each time our heart contracts, blood is ejected out of the two ventricles. Ejection fraction (EF) is a measurement of the percentage of blood leaving our heart with each contraction. Never the heart is able to pump the entire blood out of the ventricle, no matter how forceful the contraction is.

The term "EF" refers to the percentage of blood that is pumped out of a filled ventricle with each heartbeat. EF is dependent on the myocardial contractility.[4] Usually, the left ventricular EF (LV EF) is measured, as the left ventricle is the main chamber that pumps oxygenated blood to supply all parts of the body. An EF of 55% or more is considered as normal.

Cardiovascular changes during diving are not a widely studied area as there is limitation for the study, due to lack of suitable technology for assessing the cardiac parameters.

Two-dimensional echocardiography is a feasible method to study the cardiovascular changes during breath-hold immersion of the face in water.[5] Earlier workers did their observations by conducting experiments mostly on marine mammals. Very few studies were done on humans. Moreover, such a study needs a group of well-trained divers, not easy to be found. Hence, the method employed in the current study may provide an easier, cost-effective way to assess the cardiac changes during "face immersion in water" which closely mimics diving. Further, it is not associated with the risk of aspiration of water, as the participants are always free to lift up their heads from the water basin. It was already pointed out that earlier studies were focused more on changes in the heart rate, this study intends to take into account the change in the EF during simulated diving.

MATERIALS AND METHODS

The present study was undertaken in the Department of Physiology in association with Department of Cardiology, Kasturba Medical College, Manipal, Karnataka.

The Institutional Ethical Committee clearance was obtained before the study. The study was conducted after explaining to the participants about the procedure involved in their local language and after obtaining written informed consent from the participants. A detailed medical history was taken, and clinical examination was done to exclude any underlying medical condition.

Study Sample

The study was conducted in 15 male swimmers of age group 25–35 years, who are used to active breath-hold swimming. The participants are regular swimmers, who are used to swimming at least 2–3 h in a week. Non-swimmers and participants with known cardiovascular and respiratory diseases were totally excluded from the study.

Procedure

The procedure was conducted in a posture such that the participant has to immerse his face in a basin of water at room temperature for about 20 s. The participants were instructed to hold their breath as long as possible during the period of immersion of the face in water. No strict time limit was given. Echocardiographic recording was done before, during, and after the procedure.

GE VIVID 7 Ultrasound machine was used throughout the study. The values of the different cardiac parameters under the study were directly displayed on the screen. Print version of the report was also available. The changes in LV EF before, during, and after the procedure were noted down.

Electrocardiographic recording was done using Lead II ECG, to record the heart rate of the participant before, during, and after the procedure by placing electrodes in the right infraclavicular, left infraclavicular, and left iliac area of the participants.

Statistical Analysis

Analysis of the data obtained for LV EF before and during breath-hold immersion of the face in water was done using the Wilcoxon-signed ranks test (non-parametric test) for paired data.

RESULTS

Changes in LV EF before and during the immersion of the face are presented in Table 1. As shown in Table 2, the median value of LV EF in the basal condition is comparatively higher than that during breath-hold immersion of the face in water. This reduction in LV EF was found to be statistically significant ($P < 0.05$). Box plots showing the median values

Table 1: Changes in LV EF before and during the immersion of the face

Sr. No. of participants	LV EF (%)	
	BI	DI
1.	63	53
2.	52.5	46.5
3.	68	66.6
4.	59	51
5.	57	50.7
6.	52	52
7.	56	55.8
8.	50	57
9.	52.8	50
10.	63.2	48.9
11.	57.8	55.6
12.	59	54
13.	64	72
14.	63	53
15.	52.5	46.5

LV EF: Left ventricular ejection fraction, BI: Before immersion, DI: During immersion

Table 2: Comparison of the values obtained in the basal and during breath-hold face immersion in water using non-parametric test

Parameter	Median		Interquartile range		*P*
	Basal	DI	Basal	DI	
EF (%)	57	53	(52.63)	(50.55)	0.038*

*P<0.05 is taken as significant. DI: During immersion, EF: Ejection fraction

for LV EF during basal and breath-hold face immersion in water are given Figure 1.

DISCUSSION

In the present study, the change in LV EF during basal and breath-hold immersion of the face in water was studied in 15 healthy known swimmers. It was observed that there is a statistically significant reduction of LV EF during breath-hold immersion of the face in water as compared with the basal value. The present study also confirms the previous observation of a reduction in heart rate (bradycardia) which was associated with breath-hold diving.[6]

Previous studies have shown that there is a statistically significant increase in LV end-diastolic volume (EDV) during breath-hold immersion of the face in water.[7] There are studies on LV end-systolic volume, which also shows a statistically significant increase in the value during breath-hold immersion of the face in water. Bradycardia is a noted feature of breath-hold immersion of the face in water, due to which the ventricular diastole will be prolonged, which in turn will lead to an increase in the LV EDV. Bradycardia and associated arrhythmias including supraventricular tachycardia have been reported with breath-hold immersion of the face in water.[8]

Myocardial contractility is an important factor that contributes to efficient cardiac pumping activity or in other words the stroke volume. It has also been shown in the previous studies that there is increase in parasympathetic activity to the heart during breath-hold immersion of the face in water, due to stimulation of trigeminal nerve endings on the face.[9] The impulses from the trigeminal nerve endings are integrated at the medullary cardiovascular centers which in turn will increase the parasympathetic discharge to the heart.

LV EF is the fraction of blood that is pumped out of the left ventricle during each cardiac systole. It is dependent on the LV EDV and LV stroke volume.[10] In cardiovascular physiology, EDV is the volume of blood in the right and/or left ventricle at the end load or filling in (diastole). Because greater EDV causes greater distension of the ventricle, EDV is often used synonymously with preload, which refers to the length of the sarcomeres in cardiac muscle before contraction (systole). An increase in EDV increases the preload on the heart and, through the Frank-Starling mechanism of the heart, increases the amount of blood ejected from the ventricle during systole (stroke volume).

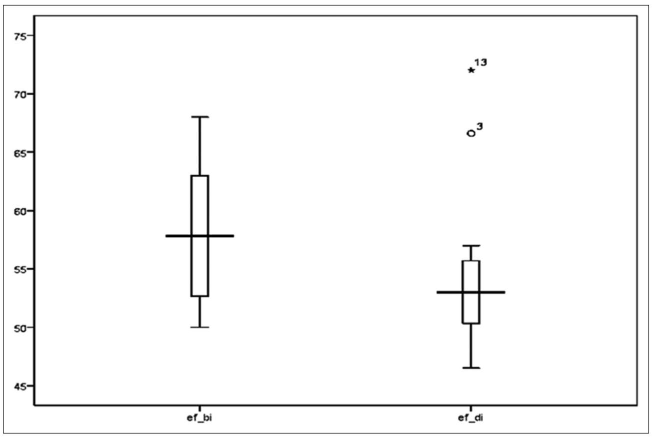

Figure 1: Comparison of the median value for left ventricular ejection fraction during basal and breath-hold face immersion

The reduction in LV EF as observed in the present study can thus be explained with respect to a reduction in myocardial contractility, which is due to an increase in parasympathetic discharge to the heart.

However, this study has its own limitation as it was conducted in a laboratory setting as compared to actual diving where other hemodynamic mechanisms will also contribute to the cardiovascular changes. However, it has been reported that cardiovascular changes during simulated diving can be extended to actual diving also. Another limitation was the face immersion time, which varied from one participant to another throughout the study.

CONCLUSION

Cardiovascular changes during breath-hold immersion of the face in water are important as a majority of our population is involved with water-related activities for leisure, sports, or livelihood. Moreover, swimming pools are there in most of the major establishments. Accidents associated with water-based activities are not uncommon also. The change in the cardiac parameter, LV EF can be extrapolated to the case of actual swimming. More studies involving changes in LV EF during actual swimming and diving are required to establish the relationship. After establishment of the two, these changes can be conveniently used to assess the cardiac fitness for professionals who are involved with water-based activities.

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