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Assessment of the Population Dynamics of *Cirrhinus Mrigala* from the Indus River: Addressing the Public Health Concerns

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ABSTRACT

Cirrhinus mrigala (Mrigala carp) is one of the major carp species widely distributed in the Indus River system and holds high economic and ecological importance in Pakistan. The present study examined the population dynamics of *Cirrhinus mrigala* in the Chashma Barrage section of the Indus River crossing Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan. The fish samples were obtained from the local fishermen using gill nets, cast nets, and purse nets of varying mesh size during monthly field surveys from November 2025 to April 2026. Total length and body weight were obtained using the standard fisheries biology method. To assess the status of the population, the following population parameters were analyzed: length-weight relationship, growth pattern, mortality rates, recruitment pattern, and exploitation level. The pooled sample had a large variation in length and weight, suggesting that there are several classes of the population size. The length-weight relationship showed positive allometric growth ($b > 3$), implying the weight of fish increased at a greater rate as compared to length. Fish stock exploitation rate and mortality rate analyses showed that the fish stock in the study area is in a moderate stage of exploitation and still sustainable. The recruitment pattern revealed a fairly regular addition to the population with the highest recruitment rate in the monsoon season. The results obtained in the present study suggest that the fish community of *Cirrhinus mrigala* in the Chashma Barrage region of the River Indus is fairly stable with a sound population structure.

Keywords: *Cirrhinus Mrigala*, Population Dynamics, Length-Weight Relationship, Fisheries Management.

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INTRODUCTION

The term population dynamics can describe the trends and mechanisms that determine changes in the size, structure, and distribution of populations. Knowing the dynamics of the population can be critical in gauging fish stocks, deciding sustainable harvest rates, and executing a successful fisheries management approach. The age structure, rate of growth, mortality, recruitment, as well as the rate of exploitation are parameters that are vital in terms of the biological status of fish populations. The evaluation of population dynamics has not only been known to provide the ecological responses of species to environmental and anthropogenic pressures but also to inform conservation policy (Ali *et al.*, 2014).

Cyprinidae is representative of about 376 genera and 3160 species of freshwater fish in the world. They exist in the world's freshwater, brackish water, and seawater, but are mainly freshwater species. Carps belonging to warm-water fishes are the most important part of Ichthyofaunal in the Indus Plain of Pakistan's freshwater rivers, and they are extensively developed and widely cultured in Pakistan (Surasinghe *et al.*, 2019). This important carp family of freshwater fish originated in Southeast Asia and spread to Asia, Europe, North America, and Africa (excluding Madagascar) to other regions of the world (Gausmann, 2021). Carp are regarded as the primary source of protein in Pakistani waters, including Morakhi (*C. mrigala*), Thaila (*C. catla*), and Rohu (*L. rohita*), and desirable species of high economic value are cultivated. This family is scattered in 4 subfamilies containing 26 genera with 65 species in Pakistan, and the biggest subfamily, Cyprinidae represented by 43 species in 13 genera. The Cyprinidae family is also dominant in the freshwater fauna of Pakistan, with the genus *Cirrhinus*, which is represented by two species, *C. mrigala* and *C. reba*, in the hills along the Indus Plain (Machineni, 2020). *Cirrhinus mrigala* is of great socioeconomic significance to the Indus River fishery. It is a significant contributor to local fish landings, supplements commercial fishers, and finds application in aquaculture because of its fast growth and cultural flexibility (Aslam, 2022).

Anthropogenic activities are developing a growing strain on the fishery resources of the Indus River. The high rate of population increase in Pakistan has escalated agricultural intensification, industrialization, and wastewater release into urban areas, hence influencing the water quality and aquatic life. The change of flow regimes associated with abstraction of water and development of infrastructure (e.g., barrage and hydropower dam) affects spawning grounds and migration paths of fish living in rivers and can interfere with the life history (Najafzadeh, 2020). Even though *C. mrigala* has ecological and economic significance, the modern-day study on the population structure of *C. mrigala* in the Indus River around Dera Ismail Khan is limited. The current research usually dwells on the composition of species and catch statistics but overlooks life-history qualities and population parameters. Such gaps in information make it difficult to use information to make informed fishery management decisions, sustainable exploitation planning, and conservation. A poor perception of growth trends, death rates, exploitation, and recruitment pressures can result in excessively high predictions of the productivity of the stock and unwanted depletion. Thus, it is essential to conduct a systematic evaluation of the changes in population to have a baseline of information on sustainable fishery activities (Inwati *et al.*, 2025).

The current research is on the population of *Cirrhinus mrigala* that lives in the Indus River in Dera Ismail Khan, Pakistan. The sampling was done in various seasons to reflect the changes in the demographic parameters with time. The length frequency data and population parameters were evaluated with common fisheries assessment models to provide estimates of growth parameters (e.g., von Bertalanffy growth coefficient), mortality rates, and exploitation ratios. This analysis and interpretation only describe *C. mrigala* in this particular river section, which means that other species or geographical areas cannot be simply extrapolated to the research without caution. The result of this study gives the baseline biological data that are essential in managing sustainable fisheries of *Cirrhinus mrigala* in the Indus River. It also helps fisheries departments to come up with regulations including size restrictions, gear restrictions, and seasonal restrictions. Better knowledge of population dynamics can facilitate the aquaculture plan by determining the growth performance and recruitment trends. This work has academic value in the wider understanding of the cyprinid population biology and also serves as a valuable source of information in comparative studies in the future in South Asian river systems.

REVIEW OF LITERATURE

Cirrhinus mrigala is one of the important carps of India, which is a species of the family Cyprinidae and can be seen in freshwater ecosystems of South Asia like rivers, lakes, and reservoirs. It is also known as the Mrigal carp and is a good catch in fisheries and aquaculture production. It is a demersal fish species that primarily consumes organic detritus, dead vegetation, and benthos and therefore plays an important role in aquatic nutrient recycling. *C. mrigala* is widely cultivated in polyculture systems and other key carps, including *Labeo rohita* and *Catla catla*, due to its high market value, adaptability to various environmental factors, as well as growth rate. The species is also regarded as ecologically significant since it helps in sustaining the trophic balance in freshwater ecosystems, as it feeds on benthic food resources. Morphometric research studies that have recently been carried out in various barrages of the Indus River basin have shown that there is a high degree of population variation in *C. mrigala*, which means that environmental factors like water flow, heterogeneity of the habitat and food availability affect the growth patterns of the species. (Fiaz *et al.*, 2025).

The main habitat of *Cirrhinus mrigala* in Pakistan is Indus River basin. The species is commonly found in various stretches of the river such as barrages, reservoirs as well as tributaries. Research has documented that *C. mrigala* species are distributed across the Indus basin and that they are also subject to a significant diversity in both morphological features and population structure across various geographic regions. Also, the studies of genetic diversity have indicated that there is a measurable genetic difference among the populations of *C. mrigala* in the major rivers of Pakistan such as the Indus, Chenab and Ravi. The genetic diversity is having significance in the adaptation of the species and the long-term maintenance of the fish populations. (Naeem *et al.*, 2020). Additionally, the population dynamics data may help fisheries managers and policymakers in formulating relevant conservation and management policies, such as control over the level of fishing activities, protection of the habitat, and sustainable development of aquaculture.

MATERIALS & METHOD

Study Area and Duration

The current research was carried out during the period of November 2025 to April 2026 in the Chashma Barrage, on the Indus River, close to Dera Ismail Khan, Khyber Pakhtunkhwa region, Pakistan. Chashma Barrage is a compelling hydraulic in the Indus River, which offers the right habitat to a wide range of freshwater fishes because of the stable flow of water and the presence of nutrients and a varied aquatic ecosystem. The location of Dera Ismail Khan is geographically in the transitional zone between the fertile alluvial plains of the Indus River and the semi- arid western hills, which makes the region ecologically important as a source of freshwater biodiversity. The region has a richness of aquatic habitats that are conducive to the resident and migrating fish species. The study area is located between the geographical latitudes of 32°33' N to 32°56' N and longitudes of 71°22' E to 71°46' E. The region has been reported to have host populations of various commercially valuable fish species living in the Indus River system. The area was chosen as a good location where the population dynamics of *Cirrhinus mrigala* can be studied due to its ecological significance and fish resources.

Figure 1*Map of Dera Ismail Khan***Study Design**

The current study was conducted as an ecological survey in the field during the period between November 2025 and April 2026 on the Chashma Barrage stretch of the Indus River in the city of Dera Ismail Khan, Pakistan. The research design was observational and descriptive, with a population ecology study of the Indus River considering the population of *Cirrhinus mrigala* (Mrigala carp) in the selected section of the river. In the course of the study, fish samples were taken in the study area and examined in order to estimate different parameters of the population. The key parameters that were examined encompassed size-frequency distribution, the growth trends, the mortality rates, the recruitment trends, and the catch statistics of the species. The data collected were utilized in order to determine the present population situation and stock constitution of *Cirrhinus mrigala* within the study area. The results of this study is likely to be of significant importance to the study of the population dynamics of the species and could be used to develop sustainable fisheries management and conservation programs regarding this economically significant freshwater fish.

Sample Collection

The sampling of fish was carried out by monthly field surveys between November 2025 and April 2026 in the specified locations of Chashma Barrage on the Indus River with the help of local fishermen. *Cirrhinus mrigala* (Mrigala carp) specimens were caught using a mixture of gill net, cast net, and purse net with varying mesh sizes so as to get a range of representative population sizes. The geographical location of every sampling site was determined by a handheld Global Positioning System (GPS) device to achieve spatial accuracy of the sampling sites. The fish specimen collected was well preserved and taken to the laboratory, where further analysis was done. The samples were then examined in the lab, where morphometric and biological analysis was done to come up with key population parameters like size structure and growth characteristics among other ecological parameters of *Cirrhinus mrigala* in the study area.

Experimental Laboratory Work

The laboratory work related to the present study was carried out at three different facilities: The Fish Biodiversity Hatchery at Chashma Barrage, Mianwali, the Experimental Laboratory of Government Girls Degree College No.1, Dera Ismail Khan, and the Laboratory of the Department of Microbiology, Gomal University (City Campus). These laboratories are equipped with the necessary facilities and instruments required for biological examination, measurement, and analysis of fish samples. The collected specimens were transported to the laboratory, where detailed morphometric and biological

examinations were performed. Standard laboratory procedures were followed to ensure accuracy and reliability in measurements and data recording.

Analysis of Population Dynamics

To examine the dynamics of the population, the total length and body weight of each specimen were assessed by conventional fisheries biology methods. The measurement of length was performed with a measuring board, whereas body weight was measured with a digital weighing balance.

RESULTS AND FINDINGS

Fish Sampling and Species Composition

During the study period (November 2025 to April 2026), a total of 120 specimens of *Cirrhinus mrigala* were collected from the Chashma Barrage in the Indus River. Samples were taken monthly in cooperation with local fishermen by using various fishing gear such as gill nets, cast nets, and purse nets of different mesh sizes. The catch contained different size classes, thus providing a representative overview of the structure and growth of the species. The samples were transported to the laboratory where morphometric measurements and biological analysis were carried out.

Length Distribution of *Cirrhinus Mrigala*

The length of the collected specimens was between 18.5 cm and 46.2 cm in total. Most of the fish specimens were found in the length range of 26-34 cm, which indicated that the fish population was mostly medium-sized. The length-frequency distribution indicated that the most common size class was 30-32 cm with the highest frequency, and the size class represented the most numerous age group within the study area. The difference in the length distribution demonstrates that there is more than one age group represented in the population, and it is evidence that there is active recruitment and perpetual population renewal in the river system.

Weight Distribution

The body weight of the fish obtained was between 210 g and 1250 g. Most of the individuals had a body weight ranging between 400 g and 800 g, which is the most frequent length class observed in the sampling period. The recorded change in weight can be attributed to the difference in age, feeding environment, and the environmental conditions that influence the growth of the species in the area of study.

Length–Weight Relationship

The length–weight relationship of *Cirrhinus mrigala* was calculated using the standard formula:

$$W = aL^b$$

Where: W = Weight of fish (g), L = Total length (cm)

a = Intercept of the regression equation, b = Growth coefficient

The calculated length–weight relationship equation for *Cirrhinus mrigala* in the present study was:

$$W = 0.018 L^{3.12}$$

The coefficient b = 3.12 showed that there was a positive allometric increase in the fish, i.e., the fish was increasing in weight at a rate that was slightly above that at which the same was increasing in length. This increasing trend implies positive environmental factors and sufficient food supply in the research site.

Growth Pattern

Cirrhinus mrigala growth analysis showed that the species had good growth patterns in the Indus River at Chashma Barrage. Most specimens fell in the intermediate growth stages, which implies the existence of active recruitment and stable population

structure. The coefficient of growth based on the length-weight relationship estimation indicated good environmental conditions in terms of water quality, food supply, and habitable environments that favored the growth of the species.

Mortality Estimates

Mortality parameters were estimated to understand the survival status of the fish population. The total mortality rate (Z) was estimated at 1.82 year⁻¹, while natural mortality (M) was calculated as 0.92 year⁻¹. The fishing mortality (F) was estimated to be 0.90 year⁻¹, indicating that fishing pressure contributes significantly to the overall mortality of the species in the study area.

Exploitation Rate

The exploitation rate (E) was calculated using the formula:

$$E = F/Z$$

The estimated exploitation rate for *Cirrhinus mrigala* was 0.49, which is close to the optimal exploitation level ($E \approx 0.5$). This suggests that the fish stock in the study area is moderately exploited but still within sustainable limits. However, continuous monitoring is recommended to prevent overexploitation and ensure long-term sustainability of the fish population.

Recruitment Pattern

The analysis of the recruitment pattern revealed that new individuals were introduced into the population throughout the year, but a peak in recruitment was observed during the monsoon. This type of recruitment implies that the species breeds well within the river system and that there are no changes in population dynamics as far as the environmental conditions are maintained.

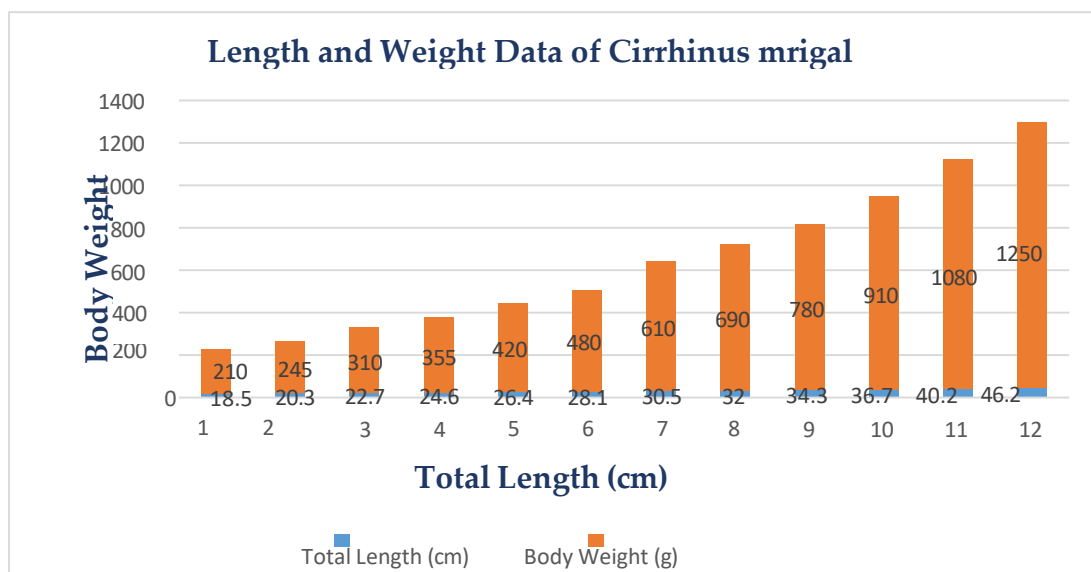
Population Status of *Cirrhinus Mrigala*

The findings of the current study research show that the number of *Cirrhinus mrigala* in the Indus River Chashma Barrage area is quite stable and has a moderate level of exploitation. The existence of the various size classes, positive allometric growth, and the regular patterns of recruitment are indicators that the species is in a healthy population structure within the study area. Nevertheless, this freshwater fish species is economically important and is therefore required to be conserved in the long run through continued monitoring and sustainable fisheries management practices.

Table 1

Length and Weight Data of Cirrhinus Mrigala

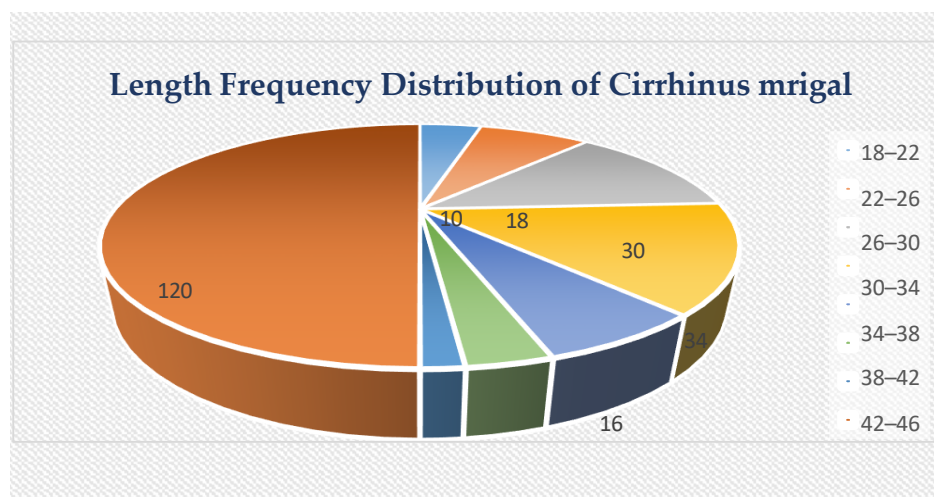
Specimen No.	Total Length (cm)	Body Weight (g)
1	18.5	210
2	20.3	245
3	22.7	310
4	24.6	355
5	26.4	420
6	28.1	480
7	30.5	610
8	32.0	690
9	34.3	780
10	36.7	910
11	40.2	1080
12	46.2	1250

Figure 2*Length and Weight Data of Cirrhinus Mrigala*

The total length of fish sampled was 18.5 cm to 46.2 cm, with body weight of 210 g to 1250 g, meaning that the population represented a diverse range of size classes.

Table 2*Length Frequency Distribution of Cirrhinus Mrigala*

Length Class (cm)	Frequency	Percentage (%)
18–22	10	8.3
22–26	18	15
26–30	30	25
30–34	34	28.3
34–38	16	13.3
38–42	8	6.7
42–46	4	3.3
Total	120	100

Figure 3*Length Frequency Distribution of Cirrhinus Mrigala*

The 30–34 cm length class showed the highest frequency, indicating that this size group dominated the population in the study area.

Table 3*Length–Weight Relationship Parameters*

Parameter	Value
Regression Equation	$W = 0.018L^{3.12}$
Intercept (a)	0.018
Growth coefficient (b)	3.12
Correlation coefficient (r)	0.96
Growth Type	Positive Allometric

The value of $b = 3.12$ indicates positive allometric growth, meaning fish gain weight faster relative to their length increase.

Table 4*Mortality and Exploitation Parameters*

Parameter	Symbol	Value
Total Mortality	Z	1.82 year^{-1}
Natural Mortality	M	0.92 year^{-1}
Fishing Mortality	F	0.90 year^{-1}
Exploitation Rate	E	0.49

The exploitation rate ($E = 0.49$) suggests that the fish stock is moderately exploited and close to the optimal exploitation level.

DISCUSSION

The current research evaluated the population trends of *Cirrhinus mrigala* that were obtained in the segment of the Indus River known as the Chashma Barrage in Dera Ismail Khan. The length-frequency distribution revealed that most individuals fell within the range of 26–34 cm in size, which indicated that most of the fish in the population were medium in size. The existence

of various classes of sizes in the sampled population indicates constant recruitment and a fairly constant population structure within the study area. The same results were reported by Fiaz *et al.* (2025), who found that *C. mrigala* populations across various barrages of the Indus River basin had varied size classes that conveyed healthy recruitment and active population turnover. Natural populations with more than one length class tend to show conditions that are conducive to the environment and that reproduction in the river system has been successful. Relationships between length and weight have been extensively employed in explaining growth patterns and physiological status of fish populations. The experimentally derived relationship between length and weight of *Cirrhinus mrigala* reported in the current study exhibited a positive allometric growth trend ($b = 3.12$), meaning that the fish increase in weight more rapidly compared to the increase in length.

These results coincide with those made by Mayank *et al.* (2017), who noted that *C. mrigala* had a positive allometric growth in the Pakistani freshwater ecosystems. Positive allometric growth is usually a good sign of good environmental conditions, including adequate food supply, proper habitat composition, and good quality of water. (Mayank *et al.*, 2017). In a manner, other research studies carried out in other freshwater ecosystems have also indicated positive allometric growth in key carp species, indicating that they can adapt to various ecological conditions without reporting a decline in their growth performance (Tariq *et al.*, 2023).

The trend in growth as seen in the current research indicates that *Cirrhinus mrigala* has healthy growth patterns in the Chashma Barrage area of the Indus River. The prevalence of the intermediate size in the population is a sign of active development periods and effective use of the food resources available. The environmental factors that affect the growth patterns in the fish populations are the temperature of water, the availability of nutrients, and the quality of the habitat. Naeem *et al.* (2020) assume that the difference in growth parameters of various populations of *C. mrigala* in Pakistan could be explained by the differences in the ecology of river systems. Moreover, the Indus River offers a dynamic water environment with seasonal variations in supply and demand, and the water flow and nutrient incorporation may contribute to productivity and fish development and survival. Both human activities and environmental conditions have a significant impact on the dynamics of fish populations in river systems. Water pollution, habitat changes, and overfishing are some of the factors that could influence the population configuration and development of fish species in the Indus River basin.

Recent research has indicated that in the tissues of the fish caught in the Indus River, there is a build-up of heavy metals and pollutants that can have adverse effects on fish health and reproductive performance (Nasir *et al.*, 2022). Also, the development of dams and barrages on the Indus River may change the natural flow regimes and modify fish migration and the ways of spawning. Irrespective of these, the findings of the current research propose that the population of *Cirrhinus mrigala* in the Chashma Barrage region is rather stable. Nevertheless, the management strategies of sustainable fisheries and environmental conservation should be used to guarantee the long-term viability of fish biodiversity in the Indus River system.

CONCLUSION

The current research was carried out in order to evaluate the population dynamics of the *Cirrhinus mrigala* of the Chashma Barrage section of the Indus River in the Dera Ismail Khan area of Khyber Pakhtunkhwa in Pakistan between the period of November 2025 -April 2026. The findings showed that the sampled population had a broad distribution of length and weight classes, implying the existence of various age groups, and that the population structure remained relatively stable at the study location. The length-weight correlation analysis indicated positive allometric growth, a positive indicator of favorable environmental conditions and a sufficient food supply for the species. Moreover, the mortality and exploitation rates indicated that the population is moderately exploited but has not reached the critical threshold of sustainability. The pattern of recruitment also showed that there was a regular entry of new people to the population, especially during the monsoon season. All in all, the evidence indicates that the *Cirrhinus mrigala* population in the region of Chashma Barrage of the Indus River is stable at present but further monitoring and application of sustainable fisheries management practices are required to maintain long-term conservation and sustainability of this freshwater fish species of economic significance in the region.

RECOMMENDATIONS

Implementation of Sustainable Fishing Practices: To avoid overexploitation of the *Cirrhinus mrigala* populations, the fisheries authorities should regulate fishing activities by restricting mesh sizes and excessive fishing pressure.

Seasonal Fishing Restrictions: During the period of spawning (monsoon period), fishing should be limited to protect the breeding stock and guarantee the success of the juvenile fish recruitment.

Regular Monitoring of Fish Stocks: These population parameters, including growth rate, mortality, and recruitment patterns, should be continuously monitored to determine the sustainability of the fish population in the long run.

Habitat Conservation: The natural environment of the Indus River should be preserved by curbing pollution, minimizing the release of industrial wastes, and ensuring that the quantity of water available in the river is of the required quality to support aquatic organisms.

Awareness and Training for Local Fishermen: The local fisheries communities must be sensitized on sustainable fisheries management and conservation strategies to ensure sustainable fishing and sustainability in the utilization of the resources.

FURTHER SCIENTIFIC RESEARCH

Future research must focus on the genetic variation, the environmental effects, and the climate change effects on the population dynamics of the *Cirrhinus mrigala* within the Indus River system.

DECLARATION

Ethical Considerations: This study strictly adhered to the Declaration of Helsinki and relevant national and institutional ethical guidelines. All procedures performed in this study were consistent with the ethical standards of the Declaration of Helsinki. The study was conducted according to ethical and clinical standards for research.

Conflict of Interest: The authors have no conflicts of interest to declare for the publication of this study.

Consent for Publication: All participants were briefed on the aims and process of the research.

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