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Analysis of Chukar Partridge Wing Morphology and Morphometry and their Implications in Flight Pattern and Behavior

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Abstract

THIS STUDY aims to investigate the attributes of wing morphology in *Alectoris chukar* birds and understand their influence on flight-related behaviors , ecology and aerodynamic capability . Ten adults healthy chukar partridge birds were used in this study, various morphometric parameters of the flattened wings were measured, including wing length, breadth, span, armwing length, handwing length, and wing area. To understand flight performance, the aerodynamic characteristics such as wing loading ratio and wing aspect ratio were calculated. While handwing index parameter used to understand the dispersal ability, feather measurements included the length, width, he inner and outer vanes length, and the length of the rachis in primaries and secondaries feathers. And for locomotion analysis a high-speed video camera used to track the wing orientation, and wing angle during the wingbeat cycle. The observations showed that the wing feathers were wide with tapered calamus. wings measurements revealed that the wing length was 24.32 ± 0.14 cm, and breadth was 13.56 ± 0.11 cm, the armwing length was 7.01 ± 0.84 cm, and the handwing length was 17.31 ± 0.99 cm, while the aspect ratio was 1.01 ± 0.17 g/cm² and the wing loading ratio was 2.21 ± 0.28. the feather length was 13.35 ± 0.9 cm, and 11.21 ± 0.18 cm in the primaries and secondaries respectively, bird fly 160 -180 meters with wing beats frequency 24.6±0.92 hertz. These data explain the relationship between wing morphology and the adaptability of the bird to different flying styles, ground foraging, and ecological distribution.

Keywords: Chukar partridge, Feathers, Wing.

Introduction

The Alectoris chukar, commonly known as the chukar partridge, is a member of the Phasianidae family within the Galliformes order [1]. Their natural range is very wide and can be found all over the Middle East and eastern parts of Asia, especially such countries as Iraq, Jordan, Palestine and Syria , Afghanistan, India and Pakistan. Chukar partridge is the national bird of in Iraq and Pakistan [2].

Within Iraq, chukar partridge is common in Sulaymaniyah, Erbil, and Duhok provinces. The birds are either kept as gamebirds for hunting or as pets because they have attractive plumage and make loud singing [3, 4]. The chukar partridge is a migratory bird, traveling away in the spring and summer for food and water. It flies during the day, up to one mile and an average flight length ranging from 40 to 300 meters [5].

The chukar exhibits strong flight as well as swift locomotion on the ground. However. The birds will jump into the air by rapid flapping of their wings before flying downhill. In more extreme conditions, the flight may change to include rising uphill at the end of the glide, short flying and walking occur regularly as the birds navigate through different areas [6].

In addition to their characteristic flight behaviors, Alectoris chukar exhibits other forms of locomotion that assist in predator evasion, including: flapping running, wing-assisted incline running, which birds flap their wings to help propel themselves while running uphill, allowing them to traverse steep terrain more rapidly [7], and wing-assisted leaping: which bird briefly flap their wings powerfully during leaping to gain additional height and distance, These supplementary locomotor strategies enable

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Alectoris chukar to quickly disperse and evade potential threats [6, 7]

Previous studies have demonstrated a strong relationship between avian wing shape and flight patterns. The aspect ratio of the wing, has a significant impact on maneuverability, rapid take-off efficiency, and gliding performance. Long, narrow wings with a high aspect ratio are associated with soaring flight, while broad, short wings with a low aspect ratio correlate with enhanced maneuverability [6, 8, 9].

The wing loading ratio, defined as a bird's body mass divided by its wing area, also exhibits a strong relationship with thrust generation and lift capabilities [8].

The wing-tip measurement, or hand-wing index, displays a notable correlation with dispersal ability, and overall flight efficiency [10]. Additionally, the morphology of wing feathers is believed to have a tight relationship with lift generation through the formation of an airfoil shape along the wing, reducing airflow resistance and aiding flapping flight [11].

Wing conformation has also been linked to foraging, migration and swimming behaviors in birds through associations with wing geometric morphometry [12]. The primary objective of this study is to investigate the morphometric characteristics of chukar partridge wings and their direct correlation with flight adaptations. this study aims to delve into specific attributes of wing morphology to better comprehend their influence on flight-related behaviors.

Material and Methods

Animals preparation

This study utilized a sample of ten adult healthy chukar (5 males and 5 females) partridge birds (*Alectoris chukar*) with age ranging from 24-32 weeks and body weights ranging from 510-556 g. The specimens were procured from certified animal vendors in Mosul city. Throughout the study duration, the birds were provided with unrestricted access to diet and water.

The research was conducted between June and September 2023 at the laboratory of the Anatomy Department, College of Veterinary Medicine, University of Mosul, Iraq.

To facilitate accurate measurements, the birds were tranquilized using intermittent inhalation of chloroform. This controlled sedation allowed for precise data collection without inducing excessive stress or harm to the birds. Subsequently, the health of the birds was carefully assessed, and they were released back into their natural habitat

Wing Morphometry and Structural Features

The flight of birds is influenced by their wing shape and structural features. To accurately study these characteristics, wing measurements were achieved using a digital caliper (LOUISWARE, China) and a measuring tape (Butterfly Brand, Singapore). The morphometric parameters were evaluated on both sides of flattened wings, encompassing wing length (L) defined as the distance between the shoulder joint and the wingtip, wing breadth (B) as the distance between the carpel joint and the tip of the first secondary wing feather, wing span (Ws) representing the distance between the two wingtips, armwing length (La) indicating the distance between the shoulder joint and the carpel joint, and handwing length (Lh) showing the distance between the carpel joint and the wingtip (Fig. 1). [8, 13].

Wing area

Further measurements were performed on the wings, including the determination of wing area (Wr). Digital wing images were captured in both flattened ventral and dorsal positions for this purpose. Subsequently, the acquired images were subjected to analysis using specialized image software (ImageJ 1.53m, NIH, US) to precisely calculate the mean wing area [14].

Aerodynamic Performance

To evaluate the aerodynamic characteristics of the wing and understanding the flight performance, we calculated both the wing loading ratio and the wing aspect ratio. The wing loading ratio (WL) was determined by dividing the body mass by the total wing area (WL = BM / Wr). On the other hand, the traditional method for calculating the wing aspect ratio (AR) involved dividing the wingspan by the mean chord, and due to the fact that the chord of a bird's wing experiences notable variations throughout its length. However, recent research has shifted its focus towards determining the aspect ratio of an individual wing. This is achieved by squaring the wing's length and dividing the result by the wing area (AR = L2 / Wr), following the method proposed by [8, 15].

In order to gain insights into flight efficiency and dispersal ability, the handwing index was measured. This index is obtained by dividing Kepp's proportion, (the distance between the longest primary flight feather (Tp), and the first secondary feather (Ts) by the wing length (L), (HWI=Tp-Ts/ L *100) (Fig. 2) [10, 16]. The abbreviations used are provided in Table 1.

Morphometry of Wing Feathers

The shape of wing feathers plays a significant role in the generation of thrust and lift in birds. For this purpose, we measured five primary and five secondary wing feathers in each bird wings. The measurements included the length and width of the feathers (FL),(FW), as well as the length of the inner and outer vanes (EV), (OV) and the length of the rachis (RL) (Fig. 3). [17]

All illustrations were generated using an (Adobe illustrator cc 2020, USA) and labeled with (EdrawMax 12.0.7) software, developed by Wondershare, USA.

Wing Locomotion Analysis

For wing locomotion Analysis, digital video camera (iX camera 210,500fps, UK), was utilized high-speed video analysis was performed to examine the wing motion. Subsequently, the recorded videos were processed using custom software, enabling precise tracking of wing position, orientation and wing plane angle across the complete wingbeat cycle [15].

Statistical analysis

Statistical analysis was performed on the morphometric data collected from both the left and right wings of most birds. The data were presented as Mean and Standard Error of Mean (M±SEM). The analysis was conducted using IBM SPSS V.25 (UK), at (P≤0.05) [18].

Results

Morphological analysis

The wings of the chukar partridge exhibit a distinguishable morphology, characterized by broad and elliptical configurations. The wings possessed a moderate length and were adorned with feathers that displayed hues of brown, grey, and white colors. These feathers varied in size and length, which categorized into five distinct regions: the primaries, secondaries, middle coverts, alula, and marginal coverts. The ventral surface of the wing mirrored the feather structure observed on the dorsal surface, although with variations in coloration and arrangements. Notably, the feathers on the ventral side were generally lighter in color, and the middle and marginal coverts on the ventral surface were comparatively shorter than their dorsal counterparts (Fig. 4).

The primary and secondary feathers were comprised of elongated, inflexible shafts that extended along the central axis of the feather structure. The outer and inner vanes comprised the expanded sections of the feathers, composed of the barbs, barbules, and the rachis. The rachis represented the segment of the shaft that extended beyond the terminal barb, eventually tapering into the calamus. The calamus, a hollow, tubular base of the feather, that positioned within the bird's integument (Fig. 5).

Morphometric analysis

The study involved comprehensive measurements of various wing dimensions, namely the wing span, armwing length, handwing length, wing breadth, aspect ratio, wing loading ratio, handwing index and wing's feather morphometry

Analysis of data obtained from a sample of 10 birds revealed that the mean wing length for both wings was 24.32 ± 0.14 cm, while the mean wing breadth was 13.56 ± 0.11 cm. Additionally, the armwing length, measured from the shoulder joint to the carpel joint of both wings, was 7.01 ± 0.84 cm, and the handwing length, measured from the carpel joint to the wing tip, was 17.31 ± 0.99 cm. Dimensions of wings is crucial, help to evaluate aerodynamics and flying patterns. It also plays a role in analyzing aspect and wing loading ratios.

In the case of the chukar partridge its wings have a shorter length compared to their depth with an aspect ratio of 2.21 ± 0.28. This unique feature allows us to examine bird agility and flying maneuvers.

Furthermore, the calculated wing loading ratio was 1.01 ± 0.17 g/cm^2 which's equivalent, to 99.04 N/m^2. This low loading ratio arises from the relatively low weight mass applied to a unit area of the wing. This characteristic assists in the evaluation of bird's proficiency during takeoff and landing

Additionally, the average handwing index for the chukar partridge wing was 42.48 ± 1.12%. This is considered moderate among different bird species, the importance of this parameter come from its application in evolution of flying efficiency and wing dispersal ability (Table 2) (Table 3).

Feathers morphometry

The length of the primary feathers was 13.35 ±0.9 cm while secondary feather with a length of 11.21 ± 0.18 The width of the primary feathers was 2.42 ± 1.12 cm while secondary feather with a width of 1.96 ± 0.19, , the outer vane length was 1.37 ± 0.17 cm for The primaries and 1.97 ± 0.53 cm for the secondaries, the mean rachis length for the primary feathers was 10.1 ± 0.07 cm and secondary feathers was 9.59 ± 0.47 cm, as well as the calamus measurements for primary was 3.25± 0.39 cm and secondary was 1.62± 1.03 cm .The data indicated that the wing feathers were compressed, and narrow, which adapted to reduce air resistance during flight, enabling the wings to bend and spread under aerodynamic loads. This structure supported by the long rachises and narrow inner and outer vanes of the flight feathers (Table 4).

Flying patterns

Through daily observations of the recorded video tracks following the controlled release of the birds, A repeatable aerial behaviors was noticed, initiated with a rapid, strong takeoff, where the bird flapped its wings and pushing its legs to propelling itself off the ground. Once aerial flying was achieved, the bird engaged in an initial phase of vertical ascent. This phase characterized by forceful wing flapping that help ascent to a notable altitude, typically ranging between 3 to 4 meters above the ground, and wing beats frequency reached to 19.3±1.04 hertz, the monitoring sessions last from 3-5 minutes.

After the vertical flying bird transits into a horizontal flight, this flying pattern was characterized by a rhythmic change between wing flapping and gliding, this pattern helps the bird to maintain a steady level of flying, sometimes the bird executes quick turning and evasive flight during the horizontal phase, the bird fly distances ranging from 160 to 180 meters with wing beats frequency measured by 24.6±0.92 hertz

When bird flying is about to end, the bird reduces its wing flapping frequency, extends its wings to regulate the angle to 90 degrees, and decreases its speed, once their feet touch the ground, the bird transitions into continuous running motion (Fig. 7).

We noticed that birds use a climbing technique called Wing Assisted Incline Running (WAIR). With WAIR the birds coordinate the movements of their wings and legs to climb cliffs at an angle of 85 to 90 degrees covering distances of, up to 5 meters.

During WAIR, the leg and wing showed matched propulsive locomotion, and wing flapping provided additional vertical and horizontal thrust against the ground. This wing-based propulsion complements the forces generated by the legs, helping forward and upward climbing of the slope (Table 5).

Discussion

The primary focus of this study was to elucidate the wing morphology of the chukar partridge and quantify the important metrics such as aspect ratio, loading ratio, wing area, and handwing index. due to their pronounced correlation with flight patterns, ecological distribution, and flight behaviors including migration and foraging. [8, 9, 15].

The elliptical and rounded wing shape of the chukar partridge is correlated with the bird's adeptness in rapid flapping and precise maneuvering. This wing morphology contributes to enhanced lift generation during flight, Research conducted by [6, 8, 9] revealed that avian species exhibiting remarkable gliding and soaring capabilities, typically possess elongated and narrow wings such as eagles and vultures, in contrast, species like pheasants and partridges, known by their maneuverability and swift movements, tend to feature elliptical wings.

Relative to other avian species, the chukar partridge wing exhibits a comparatively low aspect ratio. Studies by [15] and [19] have documented a wide range of wing aspect ratios among various bird species. For example, [15] recorded wing aspect ratios ranging from 1.8 to 5.8 across 136 water bird species, while [19] reported a range of 1.7 to 5.4 in their study of 61 bird species. The Wang and Clarke [20] supplementary database also confirmed an aspect ratio range of 2.2 to 4.3 among a large group of birds. They found that birds with low aspect ratios typically possess, broad, rounded wings

The distinctive rounded and low aspect ratio of the chukar partridge wing reflects its capacity for rapid takeoff generation, agility, and twisting maneuverability. Further insights come from Lockwood's [10] findings, demonstrating that a convex rounded wing structure imparts substantial lift, especially in slower-flying birds and those requiring rapid acceleration for takeoff and evasive maneuvers against predators. [8, 10, 15] also describe the relationship between aspect ratio and flight behavior, they found that bird species with low aspect ratios tend to engage in shorter-distance migrations. Additionally, bird species with low aspect ratios and low loading ratios require more stepovers during migration for feeding compared to those with higher aspect ratio birds.

The wing area is another parameter that influences the value of aspect ratio. Research by [19] showed that avian wings have an area ranging from 3.76 to 2423 cm2. The wing area of the chukar partridge falls within the small range bird. and, [12] observed that birds expending wing efforts tend to have smaller wing areas. This suggests that smaller wings are optimized for repetitive motions need high energy consumption. Accordingly, chukar partridges and other birds with smaller wing areas are more constrained to foraging on the ground rather than aerial hunting.

Wing loading is a important parameter that greatly influences wing structure and function. Studies on wild bird species [21] have revealed a range of wing loading (WL) ratios from 0.22 to 140 g/cm2. Additionally, [15] conducted a study on waterbirds and reported WL ratios ranging from 87.4 N/m2 (equivalent to 0.89 g/cm2) to 153.7 N/m2 (equivalent to 1.56 g/cm2).

More research on wing development in the chukar partridge [7] documented that WL values below 1g/cm2 in 50 post-hatching day-age birds. This low WL ratio in the chukar partridge explains its ability to engage in rapid takeoff and slow prolonged flying

In addition, [8, 22] reported that most bird species with low WL tend to exhibit minimized energy expenditure during long-distance flights and have a slower flying pattern. [8, 22] also they found that a combination of low aspect ratio and low WL provides birds with efficient lifting power. These findings align with the flight characteristics of the chukar partridge.

The Handwig Index represents a crucial parameter employed for the quantitative assessment of avian dispersal capacity and efficacy. It is additionally associated with the AR, [23] In the course of their investigation encompassing 41,981 museum and live avian specimens, observed that the HWI exhibited a range spanning from 0.016 to 74.8. Notably, the lowest HWI value was observed among ratites, while the highest value was recorded within the tropic bird population.

The HWI value in the Chukar partridge is notably high in the current study. This observation aligns with, [23] findings, which indicate that avian species possessing a high HWI tend to be associated with highly dispersive clades. Furthermore, these high HWI birds exhibit a global distribution. It was also observed that birds possessing HWI values within the range of 46.7 to 51.7 generally disperse across North Africa, the Middle East, and the eastern part of Asia.

Tobalske et al.[24], found that avian species with relatively higher HWI are better adapted for sustained flapping flight. This wing morphology provides birds with an enhanced ability to travel between different habitat patches, the Chukar partridge with their long, rounded wings and elevated HWI facilitate wide-ranging movements across variable terrain and at different seasonal conditions. Specifically, enable bird populations to effectively extend their foraging ranges and locate both sustenance and mates across a diverse landscape.

The feathers of the chukar partridge's wings displays a dark grey-brown hue on the dorsal surface and a lighter white shade on the ventral side. These variations in color play a substantial role in optimizing flight efficiency and boost airflow, this outcome also pointed by [25] who found that darker feathers tend to retain more heat compared to their lighter counterparts. This differences in temperature between the darker and lighter feathers leads to the creation of convective currents in the surrounding air above the bird's wings. These currents facilitate an outward flow along the wings.

Wing feather morphology differs among avian species and correlates with sex, geographic distribution, behavior, and habitat ecology. Authors [17, 26, 27] expressed that long, compressed wing feathers with semi - symmetric inner and outer vanes influence the formation of a smooth aerodynamic surface across the wings during gliding and flapping. And helps to minimize the resistance of air flows over the wing surface during flight. Feathers with these characteristics indicate lower wing loading and correspond with efficient flight performance.

In the context of a study on the ontogeny of flight in chukar partridges by [7] revealed that the escape flight behavior exhibited by chukar partridges closely aligns with that observed in mature Galliform species. This distinctive pattern is characterized by an explosive liftoff, typically occurring at heights ranging from 1 to 3 meters, followed by a phase of horizontal flight marked by rapid acceleration for several hundred meters. The flight sequence end in a shallow descending glide. This behavior is attributed to the relatively rapid onset of muscle fatigue in Galliformes, which predominantly consist of fast-glycolytic fibers reliant on unsustainable anaerobic metabolism.

On terrestrial locomotion, chukar partridges are noted to employ their hindlimbs, which possess a greater resistance to fatigue, for running activities. [7, 28] reported that adult chukar partridges, possess the capability to achieve vertical flights exceeding 4 meters in altitude and horizontal flights spanning distances of hundreds of meters, outcomes consistent with the observations made in the present study.

Moreover, [9, 28] conducted an in-depth investigation into the kinematics of chukar partridge. Their study revealed that during level of horizontal flight, these birds exhibit a wing beat frequency ranging from 20 to 22.7 hertz. In contrast, during descent, the beat frequency is slightly reduced to 20.2 hertz. Notably, [29] also provided comprehensive insights into a locomotor behavior of the (WAIR) in partridges. They elucidated that mature chukar partridges effectively employ both their wings and legs to traverse textured surfaces, including steep slopes with 105°degree angle. This locomotion strategy is particularly advantageous when these birds are fatigued from aerial flights. WAIR allows them to ascend vertical surfaces reaching heights of up to 5 meters without requiring a running start. It is worth noting that WAIR typically occurs during brief, explosive episodes, such as predator evasion or retreat to elevated perches. Furthermore, [7, 29] reported that the flapping frequency associated with WAIR in chukar partridges falls within the range of 18 to 19 hertz.

Conclusions

The study of wing morphology in chukar partridge and all parameters including loading and aspect ratios, wing area, handwing index, and the feathers characteristics, explain bird adaptability to different flying styles, foraging, and ecological distribution, these findings provide valuable information regarding the relationship between wing morphology and flight behavior, interpreting the capability of the bird to diverse flying and locomotion techniques. the relationship between wing metrics and flight behavior serve as the foundation for future avian research, by application of these metrics to other bird species, their flying styles, environmental adaptation, and even their distributions

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Conflicts of interest

Authors declared that there is no conflict of Interests.

Funding statement

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TABLE 1. The abbreviations of wing's measurements parameters

Wing abbreviations			
Abbr.	**Unit**	**Abbr.**	**Units**
Wing length = *L*	cm	Wing area =Wr	cm^2
Wing breadth = *B*	cm	Body mass = BM	g
Wing span = *Ws*	cm	Wing loading ratio =WL	g/cm^2
Armwing length = *La*	cm	Wing aspect ratio =AR	-
Handwing length = *Lh*	cm	Handwing index =HWI	-
Feather abbreviations			
Abbr.	**Unit**	**Abbr.**	**Unit**
Length of primary feather = *pFL*	cm	Length of secondary inner vane = sEV	cm
Length of secondary feather = *sFL*	cm	Length of primary outer vane = pOV	cm
Width of primary feather = *pFW*	cm	Length of secondary outer vane = sOV	cm
Width of secondary feather = *sFW*	cm	Length of primary rachis = pRL	cm
Length of primary inner vane= *pEV*	cm	Length of secondary rachis = sRL	cm

TABLE 2. the morphometric dimensional parameters in chucker partridge wings

Variables (n=10)	**Measurements (Mean ± Standard Error of Mean) \ cm**
Wing length (*L*)	24.32 ± 0.14
Wing breadth (*B*)	13.56 ± 0.11
Armwing length (*La*)	7.01 ± 0.84
Handwing length (*Lh*)	17.31 ± 0.99
Wing span (*Ws*)	52.72 ± 0.23

TABLE 3. The aerodynamic parameters in chucker partridge wings

Variables (n=10)	**Measurements (Mean ± Standard Error of Mean)**
Total Body mass (g)	541.5 ± 0.14
Wing area (*Wr*) ($cm^{2)}$	267.5 ± 3.68 s
Wing loading ratio (g/cm^2)	2.02 ± 0.07 ≈ 198.09 N/m^2 (single-wings)
	1.01±0.02 ≈ 99.04 N/cm^2 (both wing)
Aspect ratio (AR)	2.23± 0.03
Handwing index (HWI)	42.48±0.15

TABLE 4. The morphometric feathers parameters in chucker partridge wings

Variables (n=10)	**Measurements (Mean ± Standard Error of Mean)**
Length of primary feather (*pFL*)	13.35 ± 0.9
Length of secondary feather (*sFL*)	11.21 ± 0.18
Width of primary feather (*pFW*)	2.42 ± 1.12
Width of secondary feather (*sFW*)	1.96 ± 0.19
Length of primary inner vane (*pEV*)	0.64 ± 1.22
Length of secondary inner vane (*sEV*)	0.79 ± 1.24
Length of primary outer vane (*pOV*)	1.37 ± 0.17
Length of secondary outer vane (*sOV*)	1.97 ± 0.53
Length of primary rachis (*pRL*)	10.1 ± 0.07
Length of secondary rachis (*sRL*)	9.59 ±0.47
Length of primary calamus (*pCU*)	3.25±0.39
Length of secondary calamus (*sCU*)	1.62± 1.03

TABLE 5. The locomotion analysis parameters in chucker partridge wings

Variables	Wing assisting incline M±SEM	Vertical flight M±SEM	Horizontals flight M±SEM	Descent flight M±SEM
Wing beat frequency (Hz)	18.7±1.52	19.3±1.04	24.6±0.92	18.9±1.25
Body angle (deg)	88.5 ± 1.85	48.5 ± 1.78	43.1 ± 1.95	35.7± 1.19
Horizontal flight distance (m)		168.9 ±2.47		
Vertical flight distance (m)		3.75 ± 0.21		

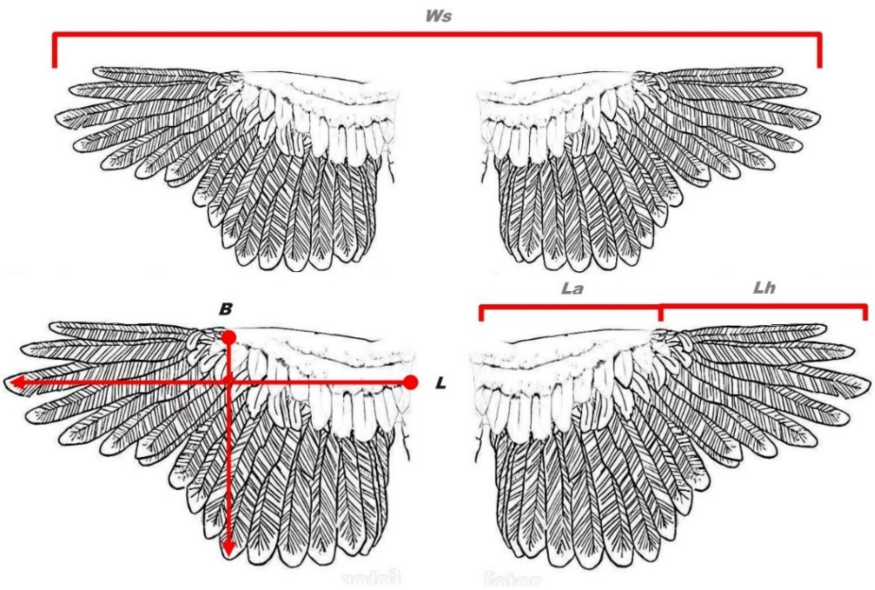

Fig. 1. illustration demonstrating the measurements plane on the wings of a chukar partridge. Includes the wing span (*Ws*), wing length (*L*), wing breadth (*B*), armwing length (*La*), and handwing length (*Lh*)

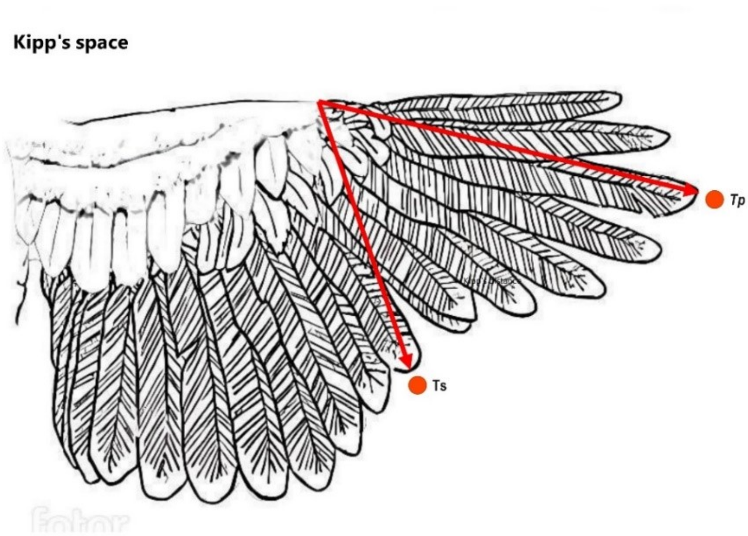

Fig. 2. illustration representing the measurements plane for Kipp's space, which is utilized to calculate the handwing index. These planes extends from the carpel joint to the tip of the longest primary feather (Tp), as well as from the carpel joint to the tip of the first secondary feather (Ts).

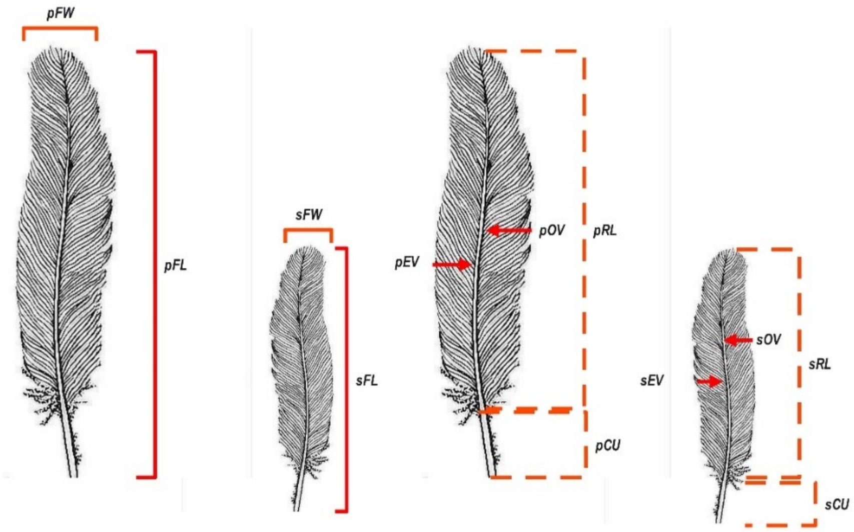

Fig. 3. illustration detailing the measurements within the primary and secondary wing feathers. includes the total length of the primary feather (*pFL*), the length of the secondary feather (*sFL*), the width of the primary feather (*pFW*), the width of the secondary feather (*sFW*), the depth of the primary inner vane (*pEV*), the depth of the primary outer vane (*pOV*), the depth of the secondary inner vane (*sEV*), the depth of the secondary outer vane (*sOV*), the length of the primary rachis (*pRL*), the length of the secondary rachis (*sRL*), the length of the primary calamus (*pCU*), and the length of the secondary calamus (*sCU*)

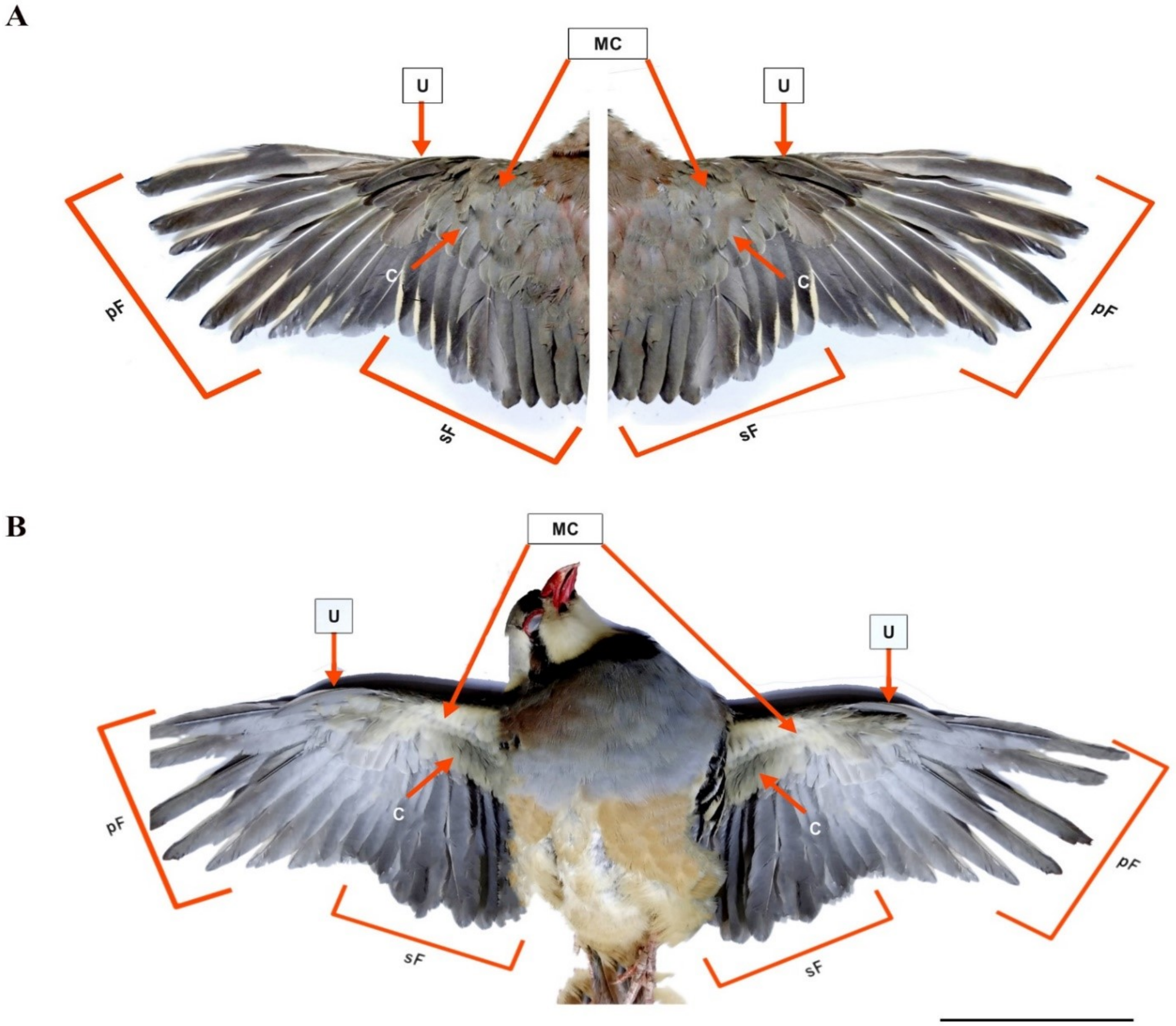

Fig. 4. image displays both the dorsal surface (A) and ventral surface (B) of a chukar partridge wing. The image delineates various feathered regions, including the primary feathers (*pF*), secondary feathers (*sF*), middle coverts (c), Alula (U) , and marginal coverts (MC), Scale bar =8 cm

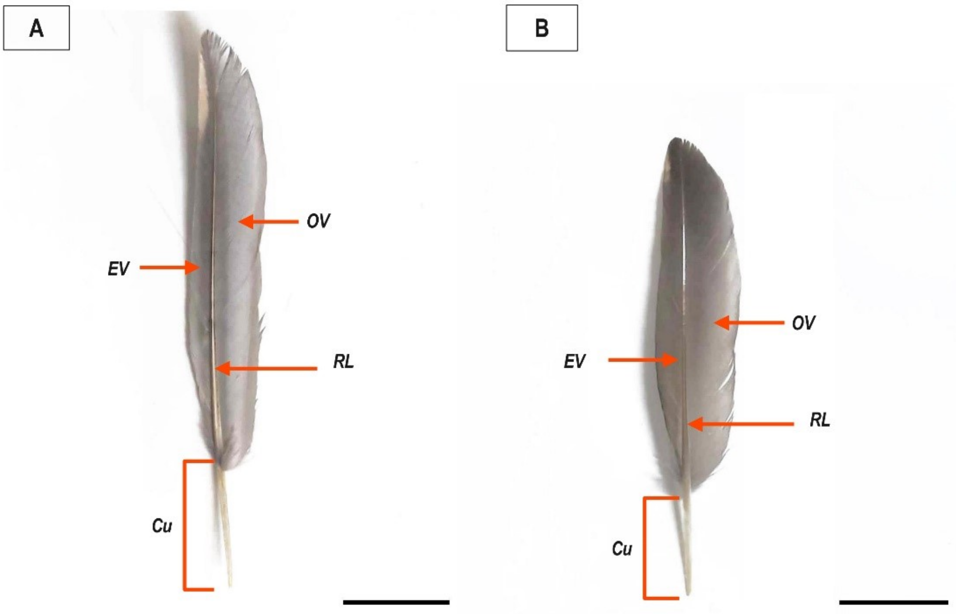

Fig. 5. Image shows the structures of wing primary feathers (A)and secondary feathers (B),including the Inner vane (EV),Outer vane (OV), Rachis (RL),Calamus (Cu), Scale bar = 3cm

Fig. 6. Graphical illustration shows the frequency distribution of wing loading ratio, wing aspect ratio, wing span, and the handwing index among the studied birds sample (n=10).

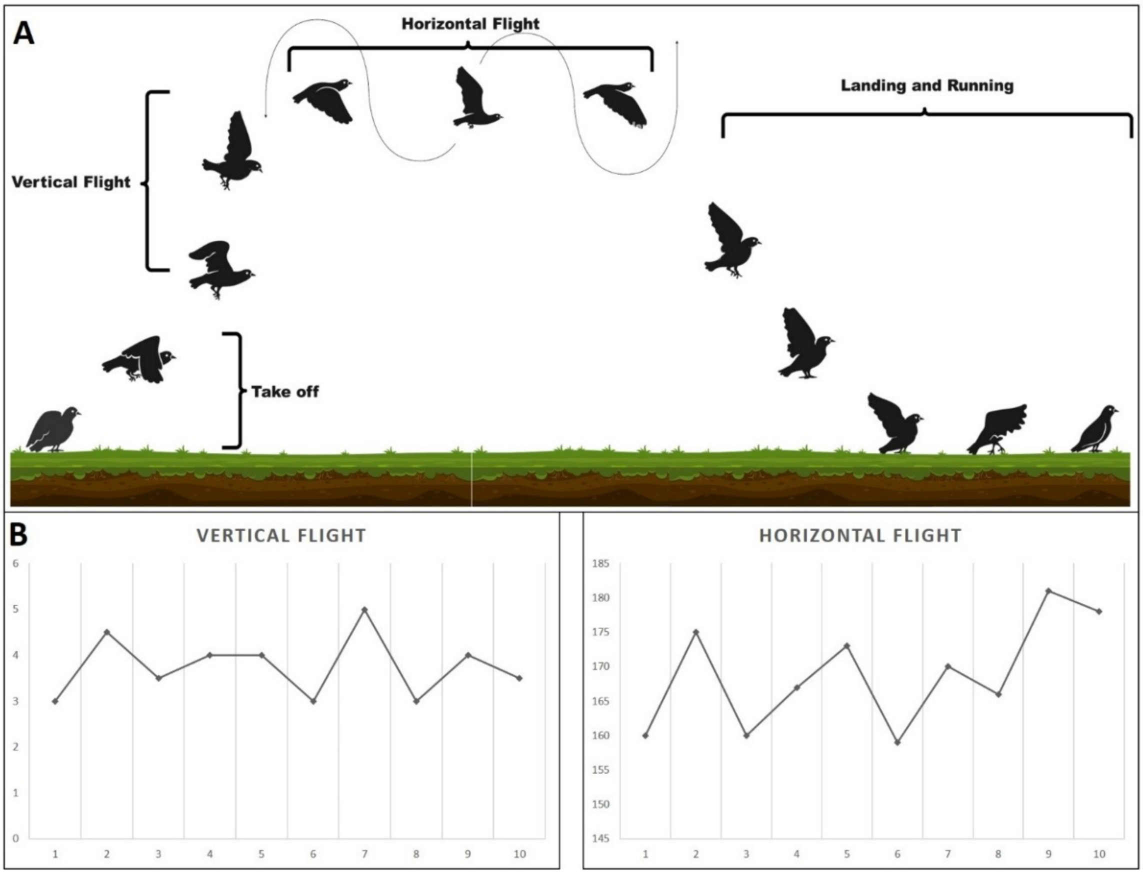

Fig. 7. illustration shows the flight sequences and behaviors of the chukar partridge (A). The illustration covers the flight phases, including the takeoff phase, vertical flight, horizontal flight, landing, and running. Furthermore, in panel (B) chart presenting a frequency distribution analysis of vertical and horizontal flights among the observed sample of birds (n=10).

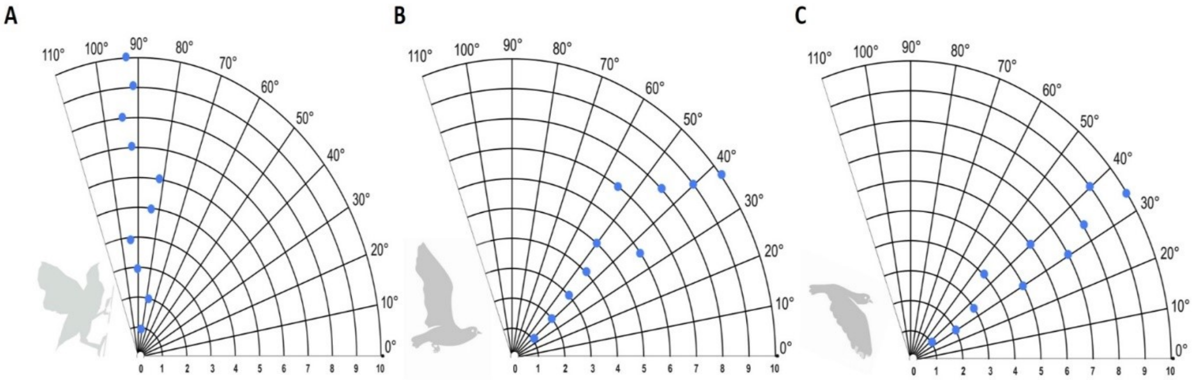

Fig. 8. Graphical illustration shows the frequency distribution of body angle during, wing assisinf icline (A), hoeizental flight (B) and during descent (C) among the studied birds sample (n=10).

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تحليل الصفات الشكلية والقياسية للجناح في حجل شوكار وتأثيراتها على نمط الطيران والسلوك

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هدفت الدراسة الحالية إلى تحري الصفات الشكلية لجناح حجل شوكار ومدى تأثيرها في طيران وسلوك الطائر، استخدم في الدراسة 10 طيور سليمة بالغة، بسطت اجنحتها وقيست مجموعة من المعلمات القياسية : شملت طول الجناح، العرض، المسافة بين الجناحين (باع الجناح)، طول الذراع، طول عظام اليد. ومساحة الجناح، ولفهم الصفات الديناميكية حسبت نسبة الحمل الهوائي والنسبة الباعية للجناح. تم حساب قابلية التشتيت الهوائي عبر قياس معامل عظام اليد . وشملت قياسات ريش الطيران الطول والعرض وطول التويج الداخلي والخارجي وطول القصبة وطول الغمد في ريش الجناح الأولي والثانوي، ولفهم كفاءة الطيران استخدمت كاميرا رقمية للتصوير السريع لتتبع اتجاهات الحركة وزوايا الجناح. أظهرت النتائج أن ريش الجناح عريض نسبيا وذات أغماد طويلة ومدببة، أما بالنسبة لقياسات الجناح ، فقد بلغ الطول 24.32 ± 0.14 سم والعرض 13.56 ± 0.11 سم وطول الذراع 7.01 ± 0.84 وطول عظام اليد 17.31 ± 0.99 سم بينما كانت النسبة الباعية للجناح 1.01 ± 0.17 غم/سم2 ونسبة الحمل الهوائي 2.21 ± 0.28. وأظهرت قياسات الريش بأن الطول 13.35 ± 0.9 سم و11.21 ± 0.18 سم في الريش الأولي والثانوي على التوالي. كشفت الدراسة عن قدرة الطائر على الطيران الأفقي على مسافة 160-180 متراً وبحركة جناح بتردد 24.6±0.92 هرتز، تفسر هذه البيانات قدرة الطائرعلى التكيف مع أنماط مختلفة من الطيران، وتكشف عن سلوكه في التغذية الأرضية والتكيف مع البيئات المختلفة، وتبين مدى تأثير الصفات الشكلية للجناح على طيران وسلوك الطائر.

الكلمات الدالة: حجل شوكار، الريش ، الجناح.