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SHORT COMMUNICATION

Life Forms of Some Representatives of r. Hedysarum Distributed in Central Asia

Myrzaali Torobaevich Umetaliev [1] **, *Zhazgul Suyunbaevna Abdyrakhmanova*** [1*] **, *Tazhimamat Kudaiberdievich Erkebaev*** [1] **, *Dinara Arynbaevna Emilbekova*** [1] **, *Aida Zhakypovna Dursunbaeva*** [1] **, *Bibigul Mamatovna Orunbaeva*** [1] **, *Ainura Manapovna Abzhaparova*** [2] **, *Kenzhekan Saypidinovna Isakova*** [1]

[1] *Institute of Natural Sciences and Agricultural Technologies, Osh State University, Osh 723500, Kyrgyzstan*
[2] *Faculty of Natural Sciences and Geography, Osh State Pedagogical University, Osh 723500, Kyrgyzstan*

ABSTRACT

The article examines the life forms of 14 species of the genus *Hedysarum* belonging to two sections (*Obscura* and *Multicaulia*) distributed in Central Asia, including the Central and Western Tien Shan (Talas, Fergana, and Alay ranges), Pamir-Alai and Kopet Dag. The morphological features of mature plants, branching types and a comparative analysis of the characteristics of the studied species—particularly those from the *Obscura* section (species *H. flavescens* and *H. denticulatum*)—were studied. Samples were collected from various types of habitats: grassy, rocky-shallow slopes, red clay outcrops, woody-shrubby thickets, archaea, spruce forests, subalpine meadows, and glacial belts. The life forms of the species were identified: *H. severzovii* and *H. pumilum* are classified as low-growing, sparsely branched shrubs with a bushy form; *H. micropterum* and *H. wrightianum* are classified as short-lived semi-shrubs, transitional from perennial herbaceous plants to short-lived shrubs; H. cephalotes is classified as a perennial turfgrass. The remaining species are perennial herbaceous plants with varying lifespans.

Keywords: Hedysarum; Plant Morphology; Central Asia; Herbaceous Plants; Vital Forms

*CORRESPONDING AUTHOR:
Zhazgul Suyunbaevna Abdyrakhmanova, Institute of Natural Sciences and Agricultural Technologies, Osh State University, Osh 723500, Kyrgyzstan; Email: jazgulabdyrahmanova@gmail.com

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1. Introduction

The genus Hedysarum (family *Fabaceae*) includes perennial herbaceous plants and semi-shrubs that are widespread in Central Asia, especially in arid and semi-arid climatic regions. These plants play an important role in the structure of vegetation cover, contribute to the stabilisation of ecosystems, enrich soils with nitrogen and serve as valuable fodder crops. The study of the life forms and ecological adaptations of *Hedysarum* provides a deeper understanding of the morpho-functional features, adaptive strategies and evolutionary specifics of representatives of the genus [1].

Morphological and anatomical studies demonstrate the high plasticity of *Hedysarum* vegetative organs in response to environmental changes. For example, *Hedysarum* theinum has characteristic anatomical and morphological features of leaves that ensure adaptation to the harsh climate of the Western Altai [2]. Similar adaptive features are observed in *H. austrosibiricum*, which has been found to exhibit morphological variability in shoots depending on growing conditions [3].

Phylogenetic studies conducted by Dzhuramurodov et al. (2022) using nuclear and chloroplast markers (ITS, matK) showed that *Hedysarum* species growing in the Pamir-Alai and Tien Shan form independent phylogenetic lines. This reflects their geographical isolation and ecological specialisation [4].

Phytochemical and anatomical analysis of *H. theinum* and *H. neglectum* conducted by Kusmangazinov et al. (2023) revealed significant differences in tissue structure and the composition of biologically active substances. These data emphasise the importance of these species as promising raw materials for the pharmaceutical industry and indicate their ecological and metabolic differentiation [5,6].

Molecular phylogenetic and chemotaxonomic studies of the genus *Hedysarum* allow us to clarify the taxonomic structure and evolutionary relationships within the group. A significant contribution to the study of the phylogeny of the genus was made by Liu et al. (2017), who showed that *Hedysarum* is not a monophyletic taxon. Analysis of five nuclear and five chloroplast sequences revealed the presence of several independent phylogenetic lines, which requires a revision of the intraspecific relationships within the tribe *Hedysareae* [7].

In turn, Nafisi et al. (2019) conducted a molecular genetic study of representatives of the *Multicaulia* section in southwestern Asia. The results showed significant diversity and deep divergence among taxa. In addition, they described a new species, *Hedysarum alamutense*, whose phylogenetic isolation was confirmed, providing the basis for revising species boundaries in this region [8,9].

A chemotaxonomic analysis conducted by Liu et al. (2019) demonstrated that the composition of biologically active substances in different *Hedysarum* species can serve as a reliable criterion for inter- and intraspecific differentiation. This emphasises the need to integrate biochemical data into systematic studies of the genus [10].

Current data indicate the high taxonomic complexity and heterogeneity of *Hedysarum*, which necessitates a comprehensive revision using morphological, molecular genetic, and biochemical approaches.

A comprehensive study of the life forms of *Hedysarum* in Central Asia remains a pressing task, especially in the context of climate change and the degradation of natural ecosystems. Representatives of this genus can play a key role in restoring vegetation cover and preserving the region's biodiversity.

2. Materials and Methods

We studied 14 species of the genus *Hedysarum*, representing two taxonomic sections: *Obscura* and *Multicaulia*. The research covered various mountainous regions of Central Asia, including the Central and Western Tien Shan (Talas, Fergana, and Alai ranges), the Pamir-Alai, and the Kopet Dagh.

From section *Obscura*, two species - *H. flavescens* and *H. denticulatum* - were examined. These species are widely distributed in the middle and upper belts of the Tien Shan and Pamir-Alai, indicating their eurythermic character.

Twelve species from section *Multicaulia* were studied: *H. songaricum*, *H. montanum*, *H. chaitocarpum*, H. severzovii, H. daraut-kurganicum, H. pumilum, H. cephalotes, H. drobovii, H. iomuticum, H. baldschuanicum, H. micropterum, and H. wrightianum.

Species of section *Obscura* occupy a wide range of habitats, including grassy and stony-fine-grained slopes, red clay outcrops, tree and shrub thickets, juniper and spruce forests along river valleys, subalpine meadows, and

glacial zones.

Species of section *Multicaulia* are mostly distributed in steppe and meadow-steppe zones of the foothills and mid-mountain belts of the Central and Western Tien Shan and Pamir-Alai. *H. micropterum* and *H. wrightianum* are restricted to the Kopet Dagh region, where they inhabit screes, rock crevices, chalky slopes, and stony-rubble substrates.

The habitats of *H. micropterum*, *H. wrightianum*, *H. severzovii*, and *H. pumilum* are specifically associated with open, dry, stony, and occasionally sandy substrates, which are characterized by minimal interspecific competition. In contrast, other species occur in a wide range of ecological conditions, from low to high mountain belts, where moisture availability varies considerably.

Field material was collected following standard botanical methods during active growth phases in early spring and spring. Morphological characteristics were recorded directly in the field and confirmed in laboratory settings. Herbarium specimens were examined and supplemented using the collections of the Botany Research Center of the Academy of Sciences of the Republic of Uzbekistan.

The studied Hedysarum species range in height from 15 to 80 cm and are characterized by early seasonal development. Life forms were analyzed through morphological features such as growth habit, branching type, and shoot longevity to classify them into distinct ecological categories.

3. Results

Section *Obscura*. *H. flavescens* – A perennial plant with erect, furrowed, slightly pubescent stems measuring 40–80 cm tall. Young plants usually have a single stem, while mature plants have 8–12 branches. The root is powerful and tapering. The leaves are 5–16 cm long and consist of 3–7 pairs of almost sessile leaflets on very short petioles. The leaflets are glabrous, oval, elliptical, sometimes with a notch at the tip in young plants, later with a short pointed tip. The leaflets are 1–2.8 cm long and 0.5–1.8 cm wide. The fruits are mainly solitary, golden-brown, oblong-obovate. Branching is up to the second, and rarely third order. Every year, the shoots die off almost to the base; in spring, new ones grow from the buds laid at the ends of last year's shoots of the first and second orders. The age of the mother stem is 8–10 years, and dead branches fall off.

H. denticulatum is a rosette-shaped bushy plant 25–50 cm tall, forming already in the first year of life. According to E.V. Nikitina (1957), the stems are underdeveloped or represented by several lower internodes with a total length of up to 20 cm. The leaves consist of 9–12 pairs of narrow-lanceolate leaflets 1.5–2.5 cm long and 0.2–0.7 cm wide, pubescent below and almost glabrous above. Flowering shoots are longer than leaves or equal to them. It is characterized by the formation of a multilayered cork insert between annual root growths in 2–3-year-old plants. The underdevelopment of the stem and the rosette arrangement of the leaves allow the species to be classified as a herbaceous rosette plant with underdeveloped stems (lifespan: 4–5 years).

Section *Multicaulia*. *H. songaricum* — A rosette plant with 4–8 shoots 25–80 cm tall (studied specimens: 25–30 cm). Stems are erect, furrowed, with sparse pubescence. Leaves are 7–15 cm long, consisting of 5–9 pairs of leaflets 1–3 cm long, 0.5–0.6 cm wide, oblong-elliptical, with upper ones being linear-lanceolate. The stems are short (1–3 cm), with numerous leaves and flower stalks at the top. The arrangement of leaves and flower stalks is similar to that of H. denticulatum.

H. montanum — A plant 40–70 cm tall (studied specimens: 28–36 cm), glabrous. Stems 5–8, ascending or almost erect, furrowed. Root taproot, up to 50 cm long, weakly branched. The leaves consist of 5–10 pairs of leaflets, young ones are pubescent, while later ones are glabrous. Leaflets are 1.3 cm long, 0.5–0.8 cm wide, oblong-lanceolate, with a rounded apex and a short tip. Branching up to the second order.

H. chaitocarpum — A plant 30–40 (up to 90) cm tall (in the studied samples: 40–50 cm). Stems 4–6 (up to 8), 8–12 cm long, erect or slightly ascending, glabrous. The central stem is often 1.5–2 times longer than the lateral stems. Leaves contain 3–8 pairs of oblong-elliptical leaflets, 3–5 cm long, 1.8–2.2 cm wide, with a short apical tip. Flower stalks are longer than the leaves.

H. severzovii — A plant 8–15 cm tall (30–35 cm in the studied samples). The root is deep, multi-headed. Stems are numerous, very short, woody at the base (3–5 cm). Annual shoots without flower stalks, 3–8 cm long. Perennial axial organs rise 12–16 cm above the soil, and annual shoots reach 16–25 cm. The mother stem is short (3–5 cm), with 2–3 first-order shoots, which produce 5–8 sec-

ond-order shoots, at the tops of which numerous third-order shoots with leaves and flower stalks form. Third-order shoots are laid in the lower and middle parts of first- and second-order shoots. The nature of branching and the presence of above-ground perennial shoots allow the species to be classified as a low-growing shrub with a dense flanking form of third-order shoots.

H. daraut-kurganicum is a loose-tufted plant with a cushion-like shape, 20–30 cm high, with 30–45 thin shoots up to 4.4 cm long. Each shoot has 3–5 leaves and flower stalks. The leaves have 4–6 pairs of leaflets, which are oblong-lanceolate. The root is powerful, penetrating deep into the soil, with few branches. The first-order shoots are thin, gathered in a bunch at the top of the root, the central ones are slightly ascending, while the lateral ones are inclined downward, which gives the plant a cushion-like shape. Given the perennial nature of the root and the two-year age of the shoots, it is assumed that the branches die off after the second year, and new ones are laid at the top of the rhizome in the third year. These features allow the species to be classified as a perennial (8–9 years) herb with short biennial above-ground shoots.

H. pumilum — Small, sparsely branched bushes 8–12 cm high (excluding flower stalks). There are 2–4 flower stalks, equal to or longer than the leaves. The stems are straight or slightly drooping, with branching up to the fourth order. There are 2 (rarely 3) first-order shoots, each producing 3 second-order shoots, continuing in a similar pattern. The numerous shoots are knotty.

H. cephalotes — A turf plant 8–10 cm tall (without flower stalks) and 16–20 cm tall with flower stalks. It has numerous short (3–6 cm) shoots of the first and second order. Annual shoots are 1–3 cm long. The root is strong and multifaceted. The underground shortened stems are covered with remnants of petioles and leaves. The leaves have 4–8 pairs of leaflets 0.4–1 cm long and 0.3–0.5 cm wide, linear-lanceolate, pubescent on both sides (more so on the underside). The species inhabits rocky and clayey slopes, in grass-wormwood groups, on alpine lawns and scree in the upper mountain belt.

H. drobovii — A sparsely branched (1–3 branches), orthotropic, densely pubescent perennial herbaceous plant 30–50 cm tall. Stems are tetrahedral, whitish due to dense pubescence. Annual shoots are single (rarely two), with 2–3 flower stalks 15–18 cm long. Flower stalks are 1.2–1.5 times longer than the leaves. There are few leaves, 1–2 pairs of leaflets, large: 4–6.5 cm long, 1–2.5 cm wide, oblong-ovate, densely pubescent on both sides. Based on the morphology of the plant, the absence of a perennial part of the stem, the formation of an atypical cork and the absence of a typical cork, this species is classified as an orthotropic life form with one, less often two or three stems, large leaves and a small number of flower stalks.

H. iomuticum — A weakly branched plant with straight, smooth, furrowed stems 10–20 cm high. Leaves are 10–15 (up to 23) cm long, with 2–4 pairs of thick leaflets 1.8–6 cm long and 1–3 cm wide. Leaf blades are on very short, thick petioles, obovate to broadly ovate in shape, the upper ones are ovate with a short pointed tip. Young leaves are densely pubescent on both sides, later becoming glabrous. Morphologically similar to H. drobovii, which allows it to be classified as a perennial (8–10 years) sparsely branched (1–3 branches), large-leaved herbaceous plant. It inhabits outcrops of variegated rocks, red clays and sandstones, in pistachio-ephemeral-wormwood communities in the foothills.

H. baldschuanicum is a perennial two- (rarely three-) stemmed plant 50–70 cm tall. The stems grow from the base, so the total height of the plant corresponds to the length of the stems. The stems are ascending. The flower stalks are 1.5–2 times longer than the leaves. The root is thin, shallow, and penetrates vertically into the soil. The leaves have 4–6 pairs of leaflets 1.5–4 cm long, 0.8–1.5 cm wide, oblong-elliptical and oblong-lanceolate in shape, with a blunt tip and a short apex, and a conical base. The first (rosette) leaves are small, with thread-like petioles, leaflets 0.5–0.7 cm long, 0.2–0.4 cm wide, obovate, with a conical base.

H. micropterum — A multi-stemmed (5–10), orthotropic bushy plant 15–20 cm tall. Leaves 5–8 cm long, with 4–6 pairs of almost sessile leaflets. Leaflets lanceolate or broadly lanceolate, apex elongated, rounded, densely pubescent on both sides. The length of the leaf is equal to or exceeds the length of the peduncle. First-order shoots are 2–3 years old, second-order shoots are annual, rise 1–2 cm above the soil and die off in autumn. The buds of annual shoots are laid in the upper part of the first-order shoots. The morphological structure, branching type, bundle structure of the xylem of annual and perennial axial organs, as well as the presence of a typical cork between the annual rings of the xylem (which is not characteristic of either grasses or shrubs)

allow the species to be classified as a low-growing (5–8 years) semi-shrub with short stems, transitional to herbaceous.

H. wrightianum — In terms of morphology, branching type and anatomical structure of the axial organs, the plant is similar to H. micropterum, differing only in its longer shoots (10–15 cm). The leaves range from oblong-ovate and broadly oval to lanceolate (**Table 1**).

Table 1. Comparative table of life forms and morphological traits of *Hedysarum* species.

Species	Section	Life Form Description	Plant Height (cm)	Stem Type / Branching	Leaf Structure	Root Characteristics	Habitat Features
H. flavescens	Obscura	Perennial, multibranched shrub	40–80	8–12 branches, furrowed	3–7 pairs, ovate to obovate, glabrous	Strong taproot	Grassy slopes, subalpine meadows
H. denticulatum	Obscura	Juvenile herbaceous rosette form	25–50	Underdeveloped stem, rosette	9–12 pairs, lanceolate, pubescent underside	Multi-layered plug in root	Shrublands, rocky outcrops
H. songaricum	Multicaulia	Rosette herbaceous form	25–30	Erect stems, sparse pubescence	5–9 pairs, oblong to lanceolate	Taproot	Meadow-steppes, mountain slopes
H. montanum	Multicaulia	Herbaceous, sparsely branched	28–36	5–8 stems, ascending	5–10 pairs, lanceolate, glabrescent	Long taproot	Foothills, dry steppe
H. chaitocarpum	Multicaulia	Medium-sized herbaceous	40–50	4–6(8) stems, central dominant	3–8 pairs, oblong-elliptic	Not specified	Mid-altitude meadows
H. severzovii	Multicaulia	Small bushy shrub, dense branching	30–35	Multilevel branching (III order)	3–5 pairs, fine rachis	Deep, multi-headed root	Open dry rocky habitats
H. daraut-kurganicum	Multicaulia	Perennial grass with cushion shape	20–30	Numerous (30–45) short shoots	4–6 pairs, lanceolate	Strong, deep root, low branching	Rocky screes, mountain ridges
H. pumilum	Multicaulia	Low shrub, multi-order branching	8–12	Up to 4th order, nodose shoots	Small, narrow leaves	Not specified	Dry rocky and sandy slopes
H. cephalotes	Multicaulia	Sod-forming perennial	8–10 (w/o peduncles)	Short shoots (1–2 order)	4–8 pairs, linear-lanceolate, densely pubescent	Strong, polygonal root	Alpine meadows, clay slopes
H. drobovii	Multicaulia	Orthotropic perennial herb	30–50	1–3 branches, strongly pubescent	1–2 pairs, large leaflets	No perennial stem part, atypical cork	Semi-desert steppes, dry grasslands
H. iomuticum	Multicaulia	Perennial, low-branched herb	10–20	Simple stems, glabrous	2–4 pairs, broad ovate	Similar to H. drobovii	Red clay, sandstone outcrops
H. baldschuanicum	Multicaulia	Perennial herb, few-stemmed	50–70	2–3 stems, ascending	4–6 pairs, oblong-elliptic	Thin root, deeply penetrating	Steppes, rocky hillsides
H. micropterum	Multicaulia	Small semi-shrub, multibranched	15–20	Branches of I–II order	4–6 pairs, lanceolate, pubescent	Xylem cork zones between annual layers	Screes, open dry slopes
H. wrightianum	Multicaulia	Similar to H. micropterum, longer shoots	15–25	Similar branching	Broad ovate to lanceolate	Same as H. micropterum	Stony screes, dry open habitats

4. Discussion

A morphological and anatomical study of species of the genus *Hedysarum* belonging to the sections *Obscura* and *Multicaulia* enables us to distinguish several life forms that reflect the adaptation of plants to the diverse condi-

tions of Central Asia.

The *Obscura* section is dominated by perennial species with well-developed above-ground and underground structures, which are characteristic of species such as *H. flavescens* — a plant with a powerful root system and perennial branching stems. This structure provides resistance to seasonal fluctuations in temperature and humidity, typical of the region's continental climate. At the same time, *H. denticulatum*, which has a rosette shape with underdeveloped stems and a short life cycle, represents the life strategy of a short-lived herbaceous plant focused on rapid completion of the growing season.

The *Multicaulia* section shows much greater diversity in life forms. Here we find:

- low-growing semi-shrubs (*H. pumilum*, *H. micropterum*, *H. wrightianum*) with a complex branching system and characteristic metameric organisation;
- herbaceous rosette plants (*H. songaricum*, *H. iomuticum*), which are sparsely branched and adapted to living in open spaces;
- small shrubs with powerful roots and perennial shoots (*H. severzovii*, *H. daraut-kurganicum*), which are adapted to living in mountainous and arid habitats.

Features of the root system, such as deep penetration and weak branching with a massive axial structure, as well as the development of perennial shoots and the specific location of renewal buds, ensure survival in conditions of limited moisture and mechanical damage in rocky and alpine biocenoses.

Of particular interest are species with intermediate characteristics, such as *H. micropterum* and *H. wrightianum*, which exhibit both semi-shrub and perennial herb traits, indicating possible evolutionary transitions between life forms within the genus.

Thus, the morphological and anatomical characteristics identified confirm the high adaptability and ecological plasticity of the genus *Hedysarum* in Central Asia. The diversity of life forms reflects both phylogenetic differences and responses to a wide range of environmental factors. A comprehensive study of life forms, morphology, and anatomy is an important direction for further investigation of the systematics and ecology of this genus.

Consequently, this species, as well as H. micropterum, belongs to the life form of small perennial semi-shrubs with relatively long stems, transitional to perennial grasses (**Table 2**).

Table 2. List of studied species of *Hedysarum* r. and their habitats.

№	Types	Location of the Species under Study
1	*H. chaitocarpum*	Fergana, Pasha-Ata river basin, north-eastern slope at an altitude of 1300 m above sea level.
2	*H. pumilum* *H. songaricum*	Syrdarya region Aulie-Ata district, Alexander ridge, opposite Akyr-Tyube, Taldy-Bulak tract at an altitude of 1500 m above sea level and Chimkent district, Karatau mountains at an altitude of 2000 m above sea level.
3	*H. Severtzovii*	Samarkand region, Khodjent district, Mogol-tau mountains, Bai-Bogut-Ata tract at an altitude of 800-1000 m above sea level.
4	*H. iomuticum*	Hissar ridge, variegated lowlands, Baisun district at an altitude of 1500-2000 m above sea level.
5	*H. cephalotes* *H. denticulatum*	Eastern Pamir, Bash-Gumbez (Zarkulskaya) river valley, middle course, first terrace at an altitude of 3000-3500 m a.s.l., Gissar ridge, Sardon-miona river basin, headwaters, pass at an altitude of 3000-3500 m a.s.l. and Eastern Pamir, Chechekti tract, Zor-Chechekti river valley at 3000 m a.s.l.
6	*H. micropterum*	Western Kopetdag (Kyurendag), vicinity of Danata spring, limestone folds of low foothills ridges.
7	*H. daraut-kurganicum* *H. flavescens*	Western Alai, left bank of the Kyzyl-Suu River, Kaman tract, hilly continental sands at an altitude of 2000-2500 m above sea level.
8	*H. Drobovii*	Pskem Ridge, the vicinity of the village of Burgmulla at an altitude of 1250-1500 m above sea level.
9	*H. wrightianum*	Turkestan; Transcaspian Mountains, Great Balkhans at an altitude of 1000 m above sea level.
10	*H. baldshuanicum*	Tajikistan. Southern Giss-Darvaza, Tiryai Ridge at an altitude of 800-1000 m above sea level.
11	*H. montanum*	Gissar ridge, variegated lowlands, Baisun district at an altitude of 1500-2000 m above sea level.

5. Conclusions

The morphological and anatomical analysis of *Hedysarum* species from sections *Obscura* and *Multicaulia* reveals significant diversity in life forms, reflecting ecological adaptations to the heterogeneous environments of Central Asia. Several distinct life forms were identified, ranging from short-lived rosette-forming herbs to long-

lived, weakly branched subshrubs and small cushion-like perennials.

Species such as *H. flavescens* and *H. severzovii* exhibit long-lived perennial growth with complex branching systems and deep taproots, indicating high adaptation to drought and mechanical stress typical of mountainous and arid habitats. In contrast, species like *H. denticulatum* and *H. songaricum* display juvenile, rosette-based life strategies with underdeveloped stems, suited to relatively moist microhabitats.

The presence of transitional forms such as *H. micropterum* and *H. wrightianum*, which show intermediate traits between herbaceous perennials and subshrubs, suggests evolutionary plasticity within the genus. Life form diversity within *Multicaulia* is notably higher than in *Obscura*, likely reflecting broader ecological amplitude and more dynamic habitat conditions.

Overall, the integration of morphological, anatomical, and life history traits provides a robust framework for understanding the ecological strategies and evolutionary differentiation within the genus *Hedysarum*, offering insights into plant adaptation across arid and montane environments of Central Asia.

Author Contributions

All authors made significant contributions to this study. Z.S.A. developed the study concept; T.K.E. developed the methodology; A.Z.D. and B.M.O. contributed to data collection and resources; D.A.E. supervised the data; A.M.A. prepared the initial draft, and K.S.I. and T.K.E. reviewed and edited the manuscript. M.T.U. supervised the study. All authors have read and approved the final manuscript.

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All data supporting the reported results are provided within the manuscript. Additional data can be made available upon reasonable request.

Conflict of Interest

All the authors declare that there is no conflict of interest in relation to the research, authorship, and publication of this study.

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