"Punch or argument?" Is the acoustic dominance behavior of *Tettigonia viridissima* males reflected in their acoustical and physical strength?

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Abstract

Any signal involved in intrasexual competition may indicate the physical strength of individuals, allowing males to gauge a competitor's fighting ability and avoid costly injuries. *Tettigonia viridissima* is an aggressive predatory bush-cricket in which males produce loud songs and engage in physical fights during choruses. This study tested whether males could assess rivals' fighting ability through acoustic signals and without physical interaction. This study hypothesized that larger males produce lower mean carrier frequencies and exhibit greater acoustic competitiveness than smaller rivals, which would be reflected in acoustic dominance behavior. Individual male calls were recorded, morphological traits were measured, and acoustic competitiveness was evaluated in a laboratory setup. Paired Wilcoxon signed-rank tests revealed no significant relationship between acoustic competitiveness and either body size or mean carrier frequency. These null results demonstrate an evolutionary asymmetry: While acoustic and morphological traits are favored by intersexual female choice, they operate independently during intrasexual male competition. Future work should evaluate alternative acoustic parameters and non-physical behavioral contexts.

Keywords

Acoustic dominance, acoustic competition, intrasexual competition, lekking, sexual selection, signal assessment, Orthoptera

Introduction

Male intrasexual competition refers to males competing with one another directly for mating access (Newman and Higham 2019). This competition has driven the development of behavioral and signal traits that enhance fitness (Newman and Higham 2019). In the animal kingdom, males frequently use signals for courtship. These signals allow rivals to compete indirectly (Alcock 2013). Such signals can represent the attractiveness of males, indicating the body condition and size or better survival strategies, reflecting the physical strength and evolutionary fitness of individuals (Davies et al. 2012). Therefore, these signals are utilized in male-male competition to enhance evolutionary individual fitness relative to rivals (Davies et al. 2012). Signal competition is not exceptional in Orthoptera. Orthoptera is an insect order that includes Ensifera (katydids, crickets, and weta, etc.) and Caelifera (grasshoppers and locusts) (Bellmann et al. 2019). Many male Tettigoniidae (katydids) and Gryllidae (crickets) stridulate with the forewings to produce sounds that attract females (Heller 1988, Ragge and Reynolds 1998, Song et al. 2020). These sounds can also represent the male's body size, reflecting their physical dominance over males (Montealegre-Z et al. 2017, Vedenina and Shestakov 2018). Information about this physical dominance might be included in acoustic signals: In several Tettigoniidae species, larger species and larger individuals produce lower carrier frequencies than smaller species or smaller individuals (Del Castillo and Gwynne 2007, Morris 2008), although carrier frequency can also depend strongly on the mechanics of sound production and stridulatory morphology (Montealegre-Z et al. 2006, 2017).

During acoustic courtship, many species of Tettigoniidae perform in a chorus (e.g. acoustic aggregation) (Greenfield 1997, 2014, Benton 2012, Hartbauer et al. 2014). Chorusing may have evolved through natural selection for two evolutionary ecological reasons. First, producing sound alone has a relatively high cost in terms of predation (Greenfield 2014). Second, because of relatively strong sound intensity, females may prefer males participating in a chorus over solitary callers (Morris et al. 1978). Thus, the chorus can involve acoustic lekking that augments strong intrasexual competition due to signal interference between individuals (Greenfield 1990, 2014, Benton 2012). The sounds of individual males in close proximity to each other produce acoustic masking, which can interfere with the ability of a female to locate a preferred male (Greenfield 2014). For example, in a study by Latimer and Sippel (1987), females of *Tettigonia cantans* did not approach a stridulating male when he produced sound with his rival in proximity.

Acoustical masking can lead to acoustic competition and physical conflicts in several species of Tettigoniidae (Morris 1971,

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Gwynne 2001). However, fighting can have high potential costs for individuals, including serious injury or death (Morris 1971, 1972, Bailey and Thiele 1983, Preston-Mafham 1990, Gwynne 2001). A male may stop producing sound when he recognizes the physical dominance of a rival based on the sound the rival is producing, thereby reducing the risk of conflict. Such acoustical winner males may also have a larger body size, which translates into greater physical strength (Gwynne 2001). Possible results of acoustic dominance behavior have been observed in several studies (Morris 1979, Shaw et al. 1981, Bailey and Thiele 1983, Arak and Eiriksson 1992). However, few hypotheses regarding acoustic dominance behavior in Orthoptera have been empirically tested (Latimer and Sippel 1987).

The great green bush-cricket (*Tettigonia viridissima*) is a unidirectional singing species (Heller 1988, Ragge and Reynolds 1998, Schul 1998, Benton 2012). To broadcast sounds widely, males of the species chorus (Arak and Eiriksson 1992). During this chorus, they will change the song pattern during interactions with rivals or physically attack their opponent (Arak and Eiriksson 1992, Benton 2012, own observation in the field). In a physical conflict, males of *T. viridissima* tend to attack the body part between the pronotum and wing, which is physiologically crucial to stridulation (Fig. 1). Thus, the prevention of injury may depend on the ability of males of this species to determine the physical strength of their rivals based on the calling sounds. For example, if the sound of a focal male indicates physical dominance over a rival male, the rival may be silent to avoid the injuries that may result from a physical battle.

Given the costs associated with physical aggression, this study addresses whether acoustic signals alone allow males to assess their rivals' fighting abilities and thereby avoid costly physical combat. If males can assess their rivals' greater physical strength based on their acoustic signals, this behavior would provide evidence of acoustic dominance of behavior in this species. In this context, acoustic dominance is expected to emerge from differences among males in physical strength, reflected by body size, and in acoustic signal strength, for which the mean carrier frequency of calls serves as a proxy (Morris 2008, Montealegre-Z et al. 2017). For example, males of the closely related species *T. cantans* produce sounds less and move away from the sound source when they confront low-frequency calls (Latimer and Sippel 1987). In addition, females of *T. viridissima* prefer males who sing frequently (Arak et al. 1990). Therefore, singing activity was used as a proxy for acoustic competitiveness. Thus, we tested whether body size and song frequency are significantly associated with acoustic competitiveness, which would support the hypothesis that acoustic dominance occurs in *T. viridissima*.

For this study, acoustic dominance was defined as a behavioral advantage in acoustic competitiveness associated with differences in body size and song frequency between rival males. Thus, we hypothesized that 1) larger males exhibit greater acoustic competitiveness than smaller males, and 2) males producing lower mean carrier frequencies display higher acoustic competitiveness than those with higher mean carrier frequency calls. We tested these two hypotheses in a laboratory at Bielefeld University in Germany. First, the songs of 33 males were recorded separately. Second, the acoustic competitiveness of the species was observed under controlled conditions. Third, the morphological traits of each individual, indicating body size, were measured and recorded. Fourth and finally, the behavior was compared with the acoustic data and morphological traits, reflected in the body size, using the paired Wilcoxon signed rank test.

Materials and methods

Calling songs of Tettigonia viridissima.—The calling song of the species is a continuous trill that consists of disyllable echemes (Heller 1988, Ragge and Reynolds 1998, Schul 1998, Rhee 2013, Grzywacz et al. 2017). Each syllable contains an opening hemisyllable (opening stroke of the wings) of low intensity before a closing hemisyllable (closing stroke of the wings) of very high

Fig. 1. Injuries of *Tettigonia viridissima* males from physical competition. Pronotum injury (detail is shown in a small box) from an attack on 6 July 2018, Senne, Bielefeld, Nordrhein-Westfalen, Germany.

intensity (Fig. 2). The time interval between the first and second closing hemisyllables is short, creating a pair (Heller 1988, Ragge and Reynolds 1998, Schul 1998, Rhee 2013, Grzywacz et al. 2017). A longer pause occurs between the second closing hemisyllable and the next pair (the third and fourth) of closing hemisyllables (Heller 1988, Ragge and Reynolds 1998, Schul 1998, Rhee 2013, Grzywacz et al. 2017) (Fig. 2). This pattern (a pair of closing hemisyllables) persists continuously. The mean carrier frequencies of the species ranges from 10 to 18 kHz (cage recording in Heller 1988, and own data) (Fig. 2, Table 1). Song terminology follows Ragge and Reynolds (1998).

Sampling and rearing.—A total of 33 male fifth (from seven nymph instar: a final instar) *T. viridissima* instar nymphs were haphazardly sampled in a meadow near Fachhochschule Bielefeld from May 20 to June 3, 2018, during the daytime (pictures of the nymphs are shown in Rhee 2019). Each individual was labeled on a sampling vial for identification during morphological measurements, individual song recording, behavioral observation, and data analysis. All animals were reared in plastic cups of the same design covered with mesh and provided with the same food (Rhee 2019) and at the same temperature (26 °C ± 1). Care and rearing conditions follow Rhee (2019).

To minimize pre-experimental acoustic exposure among individuals, adults were moved immediately after molting to different levels of a bookshelf: High-frequency carrier frequencies of Tettigoniid calls are subject to spectral denaturing when solid objects obstruct the sound sources (Arak and Eiriksson 1992, Römer and Lewald 1992, Römer 2020). The solid partitions between shelves created partial acoustic shadowing by blocking the line-of-sight sound propagation path, which interferes with direct sound transmission. While this arrangement did not provide complete acoustic isolation, it introduced more excess attenuation and distortion than in an open natural setting, serving as a conservative measure for minimizing acoustic interactions before the experiments.

The light conditions of the rearing chambers were controlled to allow for experiments to be conducted during the day (e.g., reversed photoperiod). During the preliminary experiment, it was confirmed that the males reliably called during the dark phase at room temperature. Previous studies have shown that adult *T. viridissima* males sing only at night in the laboratory when the nighttime temperature is above 22 °C, with a 12-hour light and 12-hour dark cycle (Nielsen 1972). Thus, the circadian rhythm of animals was altered during rearing from the nymph stage by controlling only the photoperiod at a relatively fixed temperature (26 °C ± 1). The photoperiod was controlled as follows: From 10 am to 10:30 pm, the room was dark. From 10:30 pm to 10 am, the room was light. In other words, the rearing chamber was controlled for 12:30 hours of light and 11:30 hours of dark.

Table 1. Measurements of morphological traits and mean of carrier frequency in *Tettigonia viridissima* (n = 19).

	Pronotum length (mm)	Femur length (mm)	Body weight (g)	Mean carrier frequency (kHz)
Range	6.51–8.61	20.11–23.76	1.13–1.64	10.71–18.96
Mean	7.16	22.28	1.37	12.97
Standard Deviation (±)	0.49	0.91	0.14	2.06

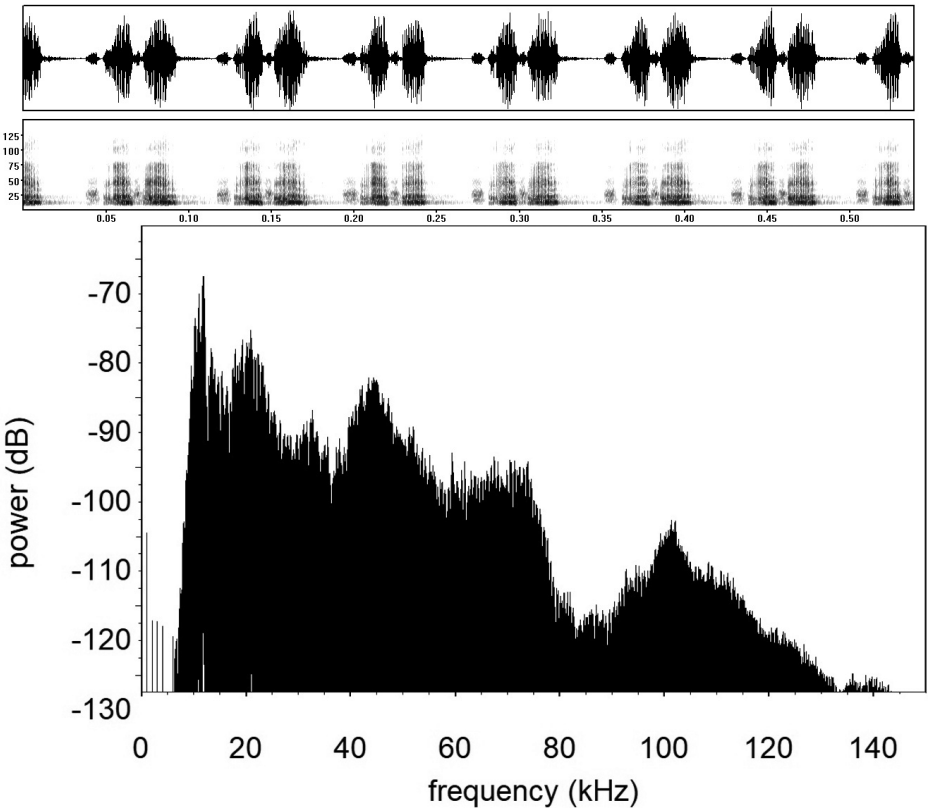

Fig. 2. Sonogram (above) and spectrogram (below) of *Tettigonia viridissima* song recorded in the laboratory. Logarithmic scale power spectrogram of an individual song for the duration of 3 minutes.

Recording the sound individually.—The ultrasound microphone Knowles FG (120 kHz recording frequencies) (Avisoft Bioacoustics) was used for song recording. This microphone was connected to an UltraSound Gate 116 Hb recording device (Avisoft Bioacoustics 2025). The recorder operated at a sampling rate of 300 kHz with 16-bit resolution. A laptop with Avisoft SASLAB Pro version 5.2 software (Avisoft Bioacoustics 2025) installed was connected to the recorder. The microphone was set at a distance of approximately 20 cm and angled at 90° from the animal to record clear and consistent sounds. The calling songs of individuals were recorded separately between July 10th and 16th 2018 (n = 19), which was one month after the first individual had ecdysis.

All individuals produced songs at a high rate. The duration of each recording was around 3 minutes, and all recordings were made between 11:30 am and 4:00 pm in an anechoic chamber under dark conditions at the Department of Evolutionary Biology, Bielefeld University in Germany. The temperature of the room remained relatively constant at 25°C ± 1. To maintain dark conditions, the plastic cup containing each individual was placed inside a closed paper box and transported from the rearing chamber to the anechoic chamber before recording. The animals were placed in the chamber 10 minutes prior to recording to allow for habituation. During habituation, conspecific acoustic stimulus, recorded on July 2, 2008 (Rhee 2013), was delivered in a continuous loop. When the animals started to produce sounds, the stimulus sound was turned off. Only a single individual was in the chamber while recording. Sounds were only recorded when they were determined to be a calling song by visualization using Avisoft software and our own hearing and knowledge.

Acoustic competition experiments.—Observational experiments were conducted in the anechoic chamber under dark conditions almost every day from July 27th 2018 to September 7th 2018, from 11:45 am to 5:00 pm when the animals were most active. All paired comparisons were conducted at the dyad level (winner vs. loser; n = 27 dyads). A total of 19 randomly chosen individuals participated in these contests. The temperature of the room was kept at 25°C ± 1. Two soft nylon meshed cages (60 × 60 × 60 cm) were used for acoustical contests. The two cages were placed on a table with one red light on either side. Based on knowledge gained during the primary experiment, the distance between the two cages and the observer was approximately 2 m, minimizing disturbance of the animal's behavior by the observer. As with the recordings, the insects were transferred to the anechoic chamber in a large paper box to maintain the light condition.

To minimize spatial learning bias, individuals involved in the preceding trial were not reused in the immediately subsequent trial. In addition, individuals on the same level of the bookshelf were not tested against each other to minimize the possibility of acoustic pre-detection. Each individual was randomly assigned to either the left or right cage before the habituation phase. The minimum habituation time was 10 minutes under dark conditions without an observer. Prior to each trial, the identification of each individual, as labeled on the cup in which they were contained, was recorded in a notebook. Singing activity has previously been used to test sexual selection in this species (Arak et al. 1990). Thus, the paired contests in this study focused exclusively on singing activity.

Based on a preliminary experiment, 20 minutes was sufficient to generate data for calculating acoustic competitiveness. Acoustic interactions were recorded using a dyad-based binary scoring scheme: At any given moment, each male was classified as either calling (1) or silent (0). Observations were organized into 1-minute bouts, a duration determined through a preliminary experiment intended to balance sensitivity to behavioral transitions with temporal consistency of scoring. Scoring of observations took two forms: 1) If both males maintained the same calling state for the entire minute, a single paired record was entered for that bout. For example, if male A called continuously and male B remained silent, both were scored once (A = 1, B = 0) in the minute. 2) If either male changed calling state during the minute, the calling state of both males was recorded at each transition. Thus, if male A changed state twice within a minute, three paired records were generated (A, B = 1,1; 0,1; 1,1). This procedure was repeated for the full 20-minute observation period. All paired records from a contest were then used to calculate acoustic competitiveness.

Morphological measurements.—The morphological traits of body weight, femur length, and pronotum length were used to determine body size and thus physical strength because these parameters are widely used for this purpose in Orthoptera (Gwynne and Bailey 1988, Del Castillo and Gwynne 2007, Whitman 2008, Montealegre-Z 2009, Montealegre-Z et al. 2017). A sliding digital caliper was used to measure femur and pronotum length in millimeters. Measurements were taken from edge to edge and after death. Body weight (g) was measured after each observed instance of acoustical dominance behavioral [Sartorius Quintix digital balance (d = 0.0001 g)].

Data and statistical analysis

Sound analysis.—All sound analyses were conducted using Avisoft SASLAB Pro version 5.2 software (Avisoft Bioacoustics). Only the closing hemisyllable was used to analyze the carrier frequencies, a decision based on three facts: First, Schul (1998) established that females use the closing hemisyllable as a conspecific signal for mating. Second, the opening hemisyllable consists of approximately -20 dB, which is -20 dB higher than the noise floor (-40 dB). Therefore, carrier frequency maxima of the opening hemisyllables are prevented by reliable automated extraction in Avisoft. Third, the closing hemisyllables exhibit distinct peaks above -10 dB, ensuring robust and repeatable measurements. The highest peak of frequencies in the spectrum of an individual was defined as the carrier frequency. The carrier frequency of every closing hemisyllable was calculated automatically by the software.

The mean of these carrier frequencies was computed by the software. In Orthoptera, carrier frequencies reflected in the first harmony are a good indicator of the acoustic strength of an individual (Morris 2008, Montealegre-Z et al. 2017). In tettigoniids, wing strokes (referred to as hemisyllables) vary, creating different carrier frequencies per stridulating wings (Ragge and Reynolds 1998, Montealegre-Z et al. 2017). Therefore, the mean of carrier frequencies was used to measure the strength of sounds (Morris 2008, Montealegre-Z et al. 2017). For each male, carrier frequency was measured based on every closing hemisyllable produced during the 2-minute recording, and a per-individual mean carrier frequency was calculated from the closing hemisyllable-level values. In subsequent analyses, these per-individual mean carrier frequencies were used as the representative pitch for each male.

Behavioral observation analysis.—For analyses of the behavioral observations, acoustic competitiveness was defined by how often an individual sang. In this study, acoustic competitiveness was treated as the total score for each individual during the dyad experiment based on their singing activities; thus, 1 point was given for each time the individual sang. The summed singing activity of each of the two individuals were then compared. The one with the higher sum was classified as the winner, and the other was deemed the

loser. For example, if male A scored 60 and male B scored 54, A was the winner and B was the loser. The contest outcome (winner or loser) was the predictor variable in the statistical model.

Statistical analysis.—The normality of the residuals was assessed before behavior observations, acoustic data, and morphological measurements were analyzed statistically. The Kolmogorov–Smirnov test (Lilliefors test) was performed for this purpose. Because residuals were not normally distributed, differences in per-individual mean carrier frequency and morphological traits between paired contest winners and losers were tested using the Wilcoxon signed-rank test (paired by dyad). All statistical analyses were carried out using R version 4.5.0 (R Core Team 2025).

Results

Mean carrier frequency did not differ significantly between winners and losers (winner vs. loser; n = 27 dyads, v = 146, p = 0.31) (Fig. 3). Pronotum length of winners did not significantly differ from pronotum length of acoustic losers (winner vs loser; n = 27 dyads, v = 251, p = 0.14) (Fig. 3). Body weight did not significantly influence the acoustic competitiveness of individuals (winner vs. loser; n = 27 dyads, v = 199.5, p = 0.81) (Fig. 4). Femur length did not significantly differ between winners and losers (winner vs. loser; n = 27 dyads, v = 240, p = 0.23) (Fig. 4).

Discussion

Contrary to expectations, this study found no significant evidence of acoustic dominance behavior in *T. viridissima*. The acoustic competitiveness of males in *T. viridissima* was not associated with body size or weight Mean carrier frequencies did not differ between winners and losers. These results indicate that acoustic competitiveness in *T. viridissima* cannot be determined by body size or mean carrier frequency under the conditions tested. It is possible that, evolutionarily, the cost of physical combat in *T. viridissima* might be lower than expected. Therefore, males may not utilize singing activity as an indicator of their rival's physical strength, with actual body size potentially playing a role only during direct physical escalation. Alternatively, the respective functions of singing activity and body

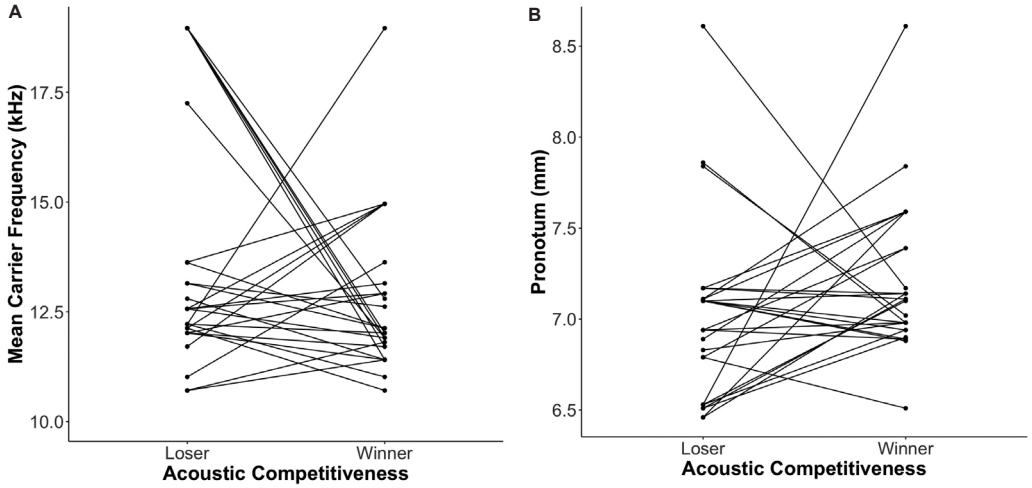

Fig. 3. A. Mean carrier frequency (kHz) difference between acoustic winner and loser individuals. Winner vs. loser: n = 27 dyads, v = 146, p = 0.31. **B.** Pronotum length (mm) difference between acoustic winner and loser individuals. Winner vs. loser: n = 27 dyads, v = 251, p = 0.14. Each line indicates dyad interaction between two individuals.

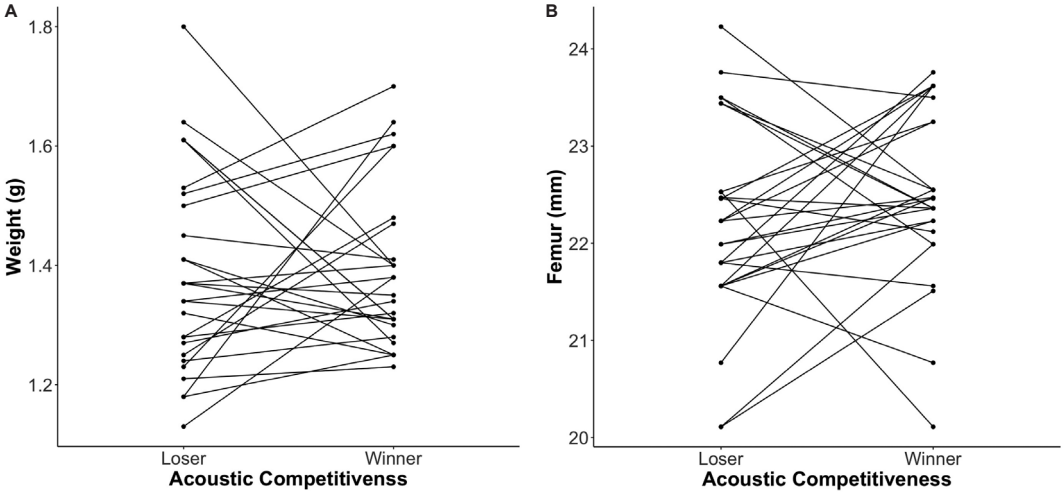

Fig. 4. A. Body weight (g) difference between acoustic winner and loser individuals. Winner vs. loser: n = 27 dyads, v = 199.5, p = 0.81. **B.** Femur length (mm) difference between acoustic winner and loser individuals. Winner vs. loser: n = 27 dyads, v = 240, p = 0.23. Each line indicates dyad interaction between two individuals.

weight might differ fundamentally between intra- and intersexual competition. In addition, the invalidity of the hypotheses may be caused by traits that were not tested, limitations of the cage or laboratory experimentor pseudoreplication due to the small sample size.

Functional differences of singing activity and body weight in female choice and male competition.—The acoustic competitiveness in this study is singing activity. Although singing activity, which correlates with body weight, is associated with female preference (Arak et al. 1990), our results show that acoustic winners and losers do not differ in body size or mean carrier frequency. While Arak et al. (1990) found that females prefer males that sing more frequently, which correlates with body weight, we found that the success of males in acoustic competition is independent of their body weight and other morphological traits related to body size. These findings suggest that the same behavioral and morphological traits are utilized differently between female choice and male intrasexual competition. Specifically, singing activity serves as a signal for female-mate choice, but the behavior does not reflect the physical attributes of males as they pertain to competition among rivals. This difference may be explained by the various physiological benefits related to fitness between males and females. Females can mate with multiple males and store sperm in their spermatheca, but sperm from only a single male is ultimately used for fertilization (Vahed 2003, 2006). This physiological selective mechanism might influence how intrasexual competition and selection shape signaling behavior through both genetic and plastic responses. In addition, the preference of females for males that sing more frequently might reflect the body condition (e.g., body weight) of males during singing. However, in *T. viridissima*, body condition might not be crucial for male intrasexual competition. Other factors, including past experience in competition or environmental resources, may be more crucial than body condition during acoustic intrasexual competition in this species. Collectively, our findings and those of Arak et al. (1990) suggest that the function of singing activity and its relation to body weight differ between intrasexual and intersexual competition and selection.

Non-tested acoustic and behavioral traits.—To determine the strength of their rivals, males of *T. viridissima* may use other traits that we did not include in this study. Our findings suggest that the closing hemisyllable operates independently of male physical evaluation, shifting the focus to alternative acoustic parameters. We used only the closing hemisyllable to analyze the carrier frequencies of the species, as this signal has very high intensity and is known as a conspecific signal during mate choice (Schul 1998). However, the opening hemisyllable might play a role in male–male competitive assessment, as shown in other species (Lin and Hedwig 2021) even if females do not respond to it. Males may potentially use such low-intensity signals for acoustic competition at close distances. Thus, based on data recorded by a highly sensitive microphone and at close distances, future studies should consider the relationship between acoustic dominance behavior and carrier frequencies of the opening hemisyllable.

Furthermore, the independence of acoustic dominance from fixed physical traits in our study underscores the potential role of environmental and behavioral contexts, rather than morphological attributes, in shaping male–male rivalry. The acoustic dominance behavior of *Tettigonia cantans*, a species closely related to *T. viridissima* (Schul et al. 1998), has been shown to be related to its territorial behavior (Schatral et al. 1984). In Schatral et al.'s (1984) study, the acoustic competition of *T. cantans* began when an intruder entered the acoustical territory of a resident, with the resident most likely to win. In the current study, there were no intruders or residents; *T. viridissima* may also require an acoustically accurate territorial background before conducting experiments. These comparisons suggest that the expression of acoustic dominance in this genus may be highly context dependent, implying that a structured social or spatial background may be a prerequisite to trigger the physical-assessment functions of these acoustic signals.

Limitations of the cage and laboratory experiments.—The independence of acoustic dominance from morphological traits in our testing environment highlights how captive settings might alter natural signaling dynamics. Some laboratory studies found leading and following songs in *Neoconocephalus spp*., but the body sizes of leaders and followers did not differ (Murphy and Schul 2017). Mean carrier frequencies in this study (13–18 kHz; Table 1) were higher than those reported from individuals caught in nature by Heller (1988; 10–12 kHz). At present, it is unclear whether this discrepancy reflects biological differences between natural and laboratory populations or methodological differences between studies, such as recording conditions and measurement procedures. However, together with the unexpectedly high proportion of brown individuals observed under laboratory conditions (Rhee 2019), these differences suggest that captive environments can influence phenotypic expression in ways not commonly observed in natural populations. Such effects may have influenced the acoustic characteristics observed in the present study.

Potential pseudoreplication due to repeated participation in dyad contests.—Due to the small sample size (n = 19 individuals, n = 27 dyads), applying dominance hierarchy models was not feasible, as such an approach requires a substantially larger number of independent dyadic interactions (Sánchez-Tójar et al. 2018). Consequently, standard non-parametric tests were used to assess behavioral patterns. Because some individuals participated in multiple dyadic trials, pseudoreplication may have been introduced, potentially reducing the statistical independence of the dataset. Accordingly, p-values should be interpreted with caution. Future studies with larger sample sizes and fully independent replicates are necessary to confirm these preliminary patterns and enable more robust modeling of dominance hierarchies.

Conclusion

Several studies have found physical dominance and interaction among male insects to be related (Kelly 2006, Umbers et al. 2012, Vedenina and Shestakov 2018, Matsuura and Miyatake 2024). However, whether and why males detect the physical strength of rivals using signals before physical combat has been studied relatively little (Stevenson and Rillich 2012). Thus, this study contributes to determining the causes of acoustic dominance by testing the hypothesis that the singing activity of male *T. viridissima* indicates the acoustic and physical strength of rivals.

Possible acoustic dominance behavior in Tettigoniids has been observed in several studies (Morris 1979, Shaw et al. 1981, Bailey and Thiele 1983, Arak and Eiriksson 1992). In Gryllids, males choose to fight or flee based on the acoustic signals of their rivals (Stevenson and Rillich 2012). For example, the low-pitched playback sounds of *T. cantans* stimulate males of the species to reduce singing and move away from the sound source (Latimer and Sippel 1987). However, Latimer and Sippel (1987) did not find a relationship between body size and carrier frequencies. In the current study, acoustic dominance was not linked with a difference in acoustic and physical strength based on the traits tested. Therefore, it was concluded that the emergence of acoustic dominance in *Tettigonia* does not reflect fixed physical traits, which aligns with the findings of Latimer and Sippel (1987). Crucially, our study highlights an evolutionary

asymmetry in *T. viridissima*. While a previous study (Arak et al. 1990) established that this singing activity functions as an honest signal for female choice, the findings of the current study demonstrate for the first time that the singing activity of *T. viridissima* operates independently of physical attributes during male–male competition.

Several acoustic and behavioral traits that were not considered parameters in this study could be crucial for measuring acoustic behavior. Furthermore, due to the relatively small sample size and the number of repeated participations, interpretation of the data requires caution. Testing hypotheses regarding acoustic dominance behavior is challenging using laboratory-reared individuals. Thus, increasing the sample size and employing modified semi-field experiments should be considered in future studies.

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Additional information

Conflict of interest
The author has declared that no competing interests exist.

Ethical statement
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The authors accept full responsibility for the content of the manuscript, including the disclosure of any use of AI.
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Data availability
All of the data that support the findings of this study are available in the main text or Supplementary Information.

Supplementary material 1

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