The domestic house cricket as a versatile model for functional aging and therapeutic testing

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Abstract

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Introduction: Aging impairs physiological and cognitive function across species, yet invertebrate models often lack the organ complexity to reflect vertebrate aging. We establish the house cricket (*Acheta domesticus*) as a scalable, biologically rich model for high-throughput assessment of age-related decline in locomotion, cognition, and behavior. Using defined life stages, we evaluate functional aging and test rapamycin, acarbose, and phenylbutyrate, individually and in combination, for their therapeutic potential.

Methods: House crickets were reared under standardized conditions and fed diets containing rapamycin, acarbose, phenylbutyrate, or their combination (SLAM). Animals underwent age-targeted or longitudinal treatment and were evaluated using open field, treadmill, Y-maze, and odor-guided escape assays. Locomotor patterns were classified via k-means clustering and cognitive flexibility was assessed through tetragram analysis. Lifespan was monitored, and post-mortem-tissues were collected for histology. Behavioral and survival outcomes were analyzed using machine learning, parametric/non-parametric tests, and Kaplan-Meier estimates. Analyses were conducted in Python and GraphPad Prism.

Results: Across >1,100 crickets, phenylbutyrate, rapamycin, and acarbose extended lifespan ($HR's = 0.50$ to 0.61, P's < 0.05), with strongest effects in females. SLAM conferred early but unsustained survival benefits ($HR = 0.37$, $P < 0.0001$). Exploratory strategy and entropy declined with age (adults vs. geriatrics: $d = 1.04$, $P < 0.0001$), but were unaffected by treatment (d's < 0.34, P's > 0.05). Olfactory discrimination diminished with age, but was rescued by acarbose, rapamycin, and phenylbutyrate (d's $= -1.82$ to -1.28, P's < 0.004), with rapamycin restoring preference in both sexes. Locomotor performance declined with age but improved with treatment. Rapamycin restored distance, speed, and running efficiency to juvenile levels (e.g., total distance: $d = -1.09$, $P = 0.0026$). Central exploration deficits were selectively reversed by rapamycin and SLAM (e.g., central time: $d = -1.48$, $P = 0.0001$). On treadmill assays, rapamycin, phenylbutyrate, and SLAM restored maximum velocity (d's $= -2.30$ to -1.32, P's < 0.0001) and running time (d's $= -2.30$ to -1.32, P's < 0.0001), whereas acarbose had no effect. Jumping distance declined only in females ($d = 1.33$, $P = 0.0063$), with partial rescue by rapamycin and acarbose in a sex-specific manner. In the escape task, aging impaired weight gain, learning, and memory (e.g., adult vs. geriatric task success: $RR = 7.20$, $P < 0.0004$). Mid-age crickets showed prolonged decision times and delayed goal-arm arrival (e.g., reward latency: d's $= -1.42$ to 1.64, P's < 0.0001 to 0.014), while geriatric performance was relatively preserved.

Conclusion: House crickets demonstrate age-related decline across survival, sensory, locomotor, and cognitive domains, which are attenuated by geroprotective interventions. Rapamycin consistently rescued performance across multiple assays, while acarbose and phenylbutyrate showed selective benefits. These findings establish the house cricket as a robust and tractable invertebrate model for aging research and cross-species drug discovery.

Keywords. House cricket, aging, anti-aging interventions, cognitive aging, translational model

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Dedication

This thesis is dedicated to my girlfriend Bethany Chu, whose unwavering support, understanding, and encouragement during long hours in the lab and at my desk have meant the world to me. I am also grateful to her family and to my small group for making Washington feel like a second home. I dedicate this work as well to my parents and my brother, whose love, perseverance, and quiet strength continue to inspire me to pursue excellence in all that I do.

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Introduction.

Aging is a universal biological process characterized by progressive declines in physiological resilience, cognitive function and cellular integrity, culminating in increased vulnerability to disease and mortality. In humans, aging is the single greatest risk factor for a myriad of chronic conditions, including neurodegenerative disorders, cardiovascular disease, and metabolic dysfunction (Niccoli & Partridge 2012; Hou et al., 2019). Despite its profound implications for public health and biomedical innovation, the study of aging in humans is inherently constrained by ethical considerations, social complexities and relatively extensive lifespan. Consequently, model organisms are indispensable for elucidating the molecular and systemic mechanisms that drive aging and for accelerating the development of geroprotective interventions (Mitchell et al., 2025; Mitchell et al., 2015).

The house cricket (*Acheta domesticus*) has emerged as a promising yet underutilized invertebrate model for aging research, offering a unique intersection of advantages not fully realized in traditional systems. Unlike established invertebrate models such as *Drosophila melanogaster* and *Caenorhabditis elegans*, which provide genetic tractability but possess highly simplified organ systems (Andersen & Winter, 2019; Patridge & Tower, 2007), the house cricket exhibits a more complex physiology, including defined organ systems and a hemimetabolous life cycle that better mirrors vertebrate aging processes (Lyn et al., 2011; Litke et al., 2018). With a relatively short lifespan, clear morphometric distinctions across age groups, and low-cost maintenance, house crickets facilitate rigorous lifespan and healthspan studies with unparalleled scalability (Figure 1) (Liao et al., 2025; Liao et al., 2024). Their ease of rearing, coupled with their physiological parallels, positions the house cricket as a powerful model for investigating age-related degeneration and testing pharmacological interventions in a framework that bridges invertebrate and vertebrate biology (Mito et al., 2022; Fuciarelli & Rollo, 2021).

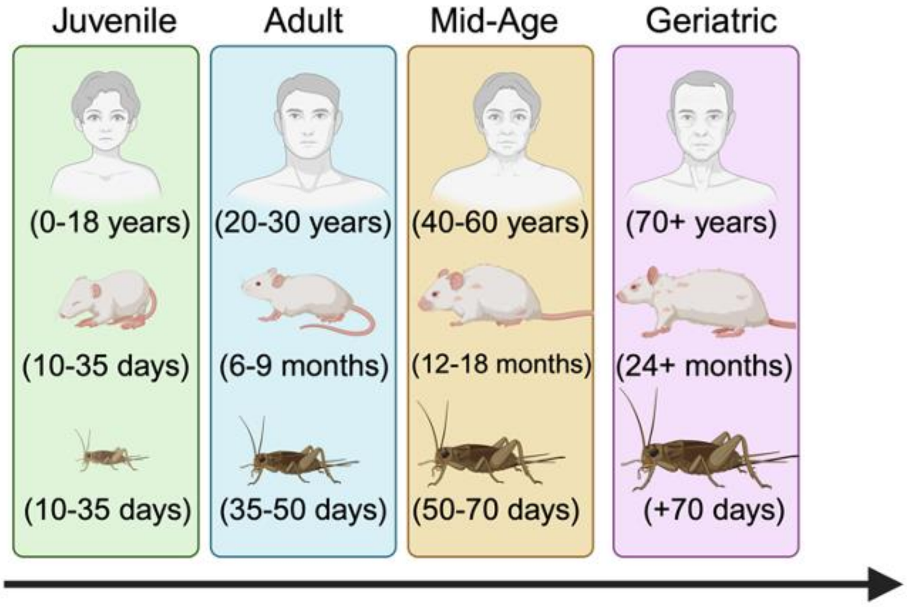


Figure 1. Translational relevance of the house cricket. Created using Biorender.com.

Aging manifests not only in cellular decline but also in the progressive deterioration of neuromuscular function, making physical performance a critical biomarker of frailty (Guralnik et al., 1989). In house crickets, the jump escape reflex, a rapid neuromuscular response essential for predator evasion, relies on precise neuromuscular activation and coordination (Card, 2012). However, aging is accompanied by impairments in neuromuscular transmission, cardiovascular function and respiratory efficiency, potentially compromising this essential survival mechanism.

Aged crickets may exhibit reduced jump distances, delayed responses, or a shift toward walking as an alternative escape strategy, mirroring age-associated declines in locomotor function observed in vertebrates (Lachenicht et al., 2010). By integrating cross-sectional assessments of locomotion and exploratory behavior, we aim to establish a comprehensive framework for quantifying frailty in the house cricket.

Beyond physical function, aging exerts profound effects on cognition, yet the underlying mechanisms remain poorly understood in invertebrate models. In mammals, decision-making, learning, and memory decline with age while anxiety-like symptoms increase (Perna et al., 2016; Li et al., 2024). A particularly compelling aspect of cricket neurobiology is adult neurogenesis (AN), a process by which new neurons are continuously generated in the mushroom bodies, brain structures analogous to the mammalian hippocampus that mediate sensory integration and learning (Cayre et al., 1994; Boldrini et al., 2018; Kempermann et al., 2018). Disruptions in AN have been linked to cognitive deficits in both vertebrates and invertebrates, with olfactory and visual stimuli playing critical roles in neurogenic modulation (Cayre et al., 2007; Scotto-Lomassese et al., 2002). Given that olfactory impairment is an early biomarker of neurodegenerative decline (Boyce & Shone, 2006; Doty, 2012; Devanand et al., 2015) and Alzheimer's-associated dementias (Murphy 2019) in humans, and neurodegeneration has been implicated in invertebrates as well (Hansson & Stensmyr 2011), assessing odor discrimination in crickets provides an additional novel, ecologically relevant assay for measuring cognitive aging.

To investigate potential interventions for aging-associated decline, we will assess the effects of three pharmacological agents, rapamycin (RAP), acarbose (ACB), and phenylbutyrate (PBA), administered individually and in combination through the concept of slowing aging by multiplexing (SLAM) (Ladiges & Liggitt 2017). These compounds were selected based on their well-established geroprotective effects in mammalian models, where they have been shown to extend lifespan and delay multiple aging phenotypes (Miller et al., 2014; Harrison et al., 2009; Ladiges & Liggitt, 2018). Rapamycin, an mechanistic target of rapamycin complex 1 (mTORC1) inhibitor, enhances autophagy and suppresses cellular senescence, thereby mitigating neurodegenerative processes and promoting vascular integrity (Ren & Zhang, 2018; Wilkinson et al., 2012). Acarbose, an α-glucosidase inhibitor, mimics the metabolic benefits of caloric restriction by improving insulin sensitivity and reducing oxidative stress (Brewer et al., 2016). Phenylbutyrate, a histone deacetylase (HDAC) inhibitor and ammonia scavenger, plays a pivotal role in maintaining proteostasis and epigenetic homeostasis, with prior studies demonstrating its capacity to upregulate anti-inflammatory pathways and enhance cognitive resilience (Kolb et al., 2015; Khan et al., 2017).

Despite the evolutionary divergence between insects and mammals, fundamental aging processes (i.e., metabolic dysregulation, immune senescence, and neurodegeneration), are remarkably conserved across taxa (Pitt & Kaeberlein 2015). Notably, intestinal barrier dysfunction has been identified as a predictor of mortality in both *Drosophila* and vertebrate models, highlighting shared hallmarks of aging across phylogenetically distant species (Rera et al., 2012). Given that each of the selected drugs targets distinct yet complementary aging mechanisms, we hypothesize that their combinatorial administration will yield synergistic benefits, delaying physiological and cognitive decline more effectively than monotherapy, as observed in murine models (Jiang et al., 2022).

We hypothesize that the house cricket exhibits age-related declines in behavioral and cognitive function, which can be quantified through a series of behavioral assays across multiple age groups, and that there are sex-related differences. Furthermore, we propose that pharmacological intervention with the anti-aging compounds rapamycin, acarbose, and phenylbutyrate—administered individually and in combination—extends lifespan and mitigates these declines when administered intermittently in geriatric crickets. We predict that aged crickets receiving these treatments will demonstrate improved locomotor performance, neuromuscular coordination, and cognitive function compared to untreated controls. By systematically characterizing age-associated functional deterioration and assessing the efficacy of geroprotective interventions, this study aims to establish the house cricket as a scalable and translational model for aging research, bridging mechanistic insights across species.

Materials and Methods.

Cricket rearing and housing conditions. House crickets were sourced from a commercial supplier (Fluker Farms Inc, Louisiana, USA) and maintained under standardized conditions based on previously established guidelines (Liao et al., 2025). Briefly, crickets had a heterogeneous genetic background, incorporating genes from various regions across the United States. Environmental conditions were controlled to ensure physiological stability, with temperatures maintained at 29 ± 1°C and stable relative humidity levels (32 ± 3%) (Lyn et al., 2011).

To simulate naturalistic environmental conditions while ensuring containment, crickets were maintained in a dual-layer Plexiglass housing system designed to permit self-regulated light exposure. The outer enclosure served as a barrier to escape and provided thermal and environmental stability, while the inner compartments enabled experimental manipulation of photoperiods. Within this system, continuous 24-hour illumination was applied, and shading structures (e.g., stacked egg cartons) were strategically positioned to allow crickets to autonomously select their preferred light intensity, thereby mimicking natural behaviors of light avoidance and thermoregulation (Figure 2). Housing densities were maintained at 20–30 individuals per cage (10–15 cm^2/cricket) to optimize social interactions while preventing overcrowding and resource scarcity (Ghosal et al., 2009). Both sexes were co-housed to approximate natural ecological conditions. Crickets were not maintained in a specific pathogen-free (SPF) containment unit to better replicate wild-like aging trajectories (Dobson et al., 2019).

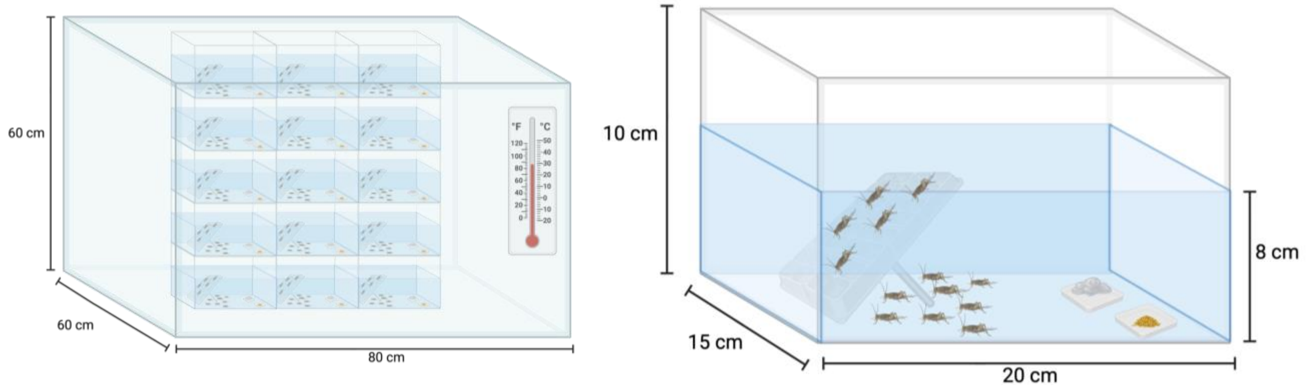


Figure 2. Schematic representation of the double enclosure system for housing crickets (left). Detailed dimensions and design features of the inner cricket habitat are provided (right). Figure created using Biorender.com.

Diet Preparation and Drug Administration. All crickets were provided with a standardized diet formulated by combining Picolab Rodent Diet 20 (5053, Irradiated; Purina Mills, USA, which contains corn, soybean, wheat, fish meal, and a vitamin-mineral mixture), with gelatin as a binding agent. The control diet was prepared by dissolving gelatin in water at 100°C, cooling to ~60°C, and subsequently mixing with rodent chow. The homogenized mixture was refrigerated at 20°C overnight before undergoing dehydration in a food dehydrator to prevent mold growth. The dried product was further homogenized using a food processor to ensure consistency. For experimental diets, drug stability and solubility were considered during preparation (Table 1):

- **Rapamycin** (14 ppm; Southwest Research Institute, San Antonio, TX) was incorporated directly into the gelatin mixture.
- **Acarbose** (1000 ppm; Spectrum Chemical Mfg Corp., Gardena, CA) was pre-dissolved in deionized water before incorporation to ensure uniform distribution.
- **Phenylbutyrate** (1000 ppm; Triple Crown America, Inc., Perkasie, PA) was added directly, considering its slight water solubility.
- **Combination drug treatment** contained rapamycin, acarbose, and phenylbutyrate at their respective dosages.

Control groups received an identical base diet without drug supplementation.

Drug	Temperature Stability Limit	Solubility in Water
Phenylbutyrate	> 40°C	Slightly soluble
Acarbose	> 50°C	Soluble
Rapamycin	> 40°C	Insoluble

Table 1. Temperature stability and solubility guidelines.

Acclimation and experimental design. Crickets arrived at the lab at 2-5 weeks of age and underwent a three-week acclimation period with *ad libitum* access to the control diet and water (delivered via Napa nectar). At the start of each experiment, cages were randomly assigned to treatment or age groups to minimize environmental bias. Water was continuously available throughout all experiments.

Drug treatment studies. At six weeks of age (42 days), corresponding to full adulthood, crickets were randomly assigned to either control or treatment groups. Drug treatments were continued until all individuals perished to assess lifespan extension effects. Mortality was monitored daily, and deceased crickets were promptly removed. 2g of food was changed and weighed weekly to assess consumption.

To evaluate short-term pharmacological effects on lifespan and behavior, a subset of crickets was assigned to an intermittent treatment group at eight weeks of age. These crickets received drug treatment for two weeks until they reached geriatric age (10 weeks old), when age-related decline is expected to be most pronounced (Liao et al., 2025). Behavioral assays were conducted at this predefined endpoint and survival monitoring was performed on a subset given control diet until all individuals naturally perished. This approach allowed for both cross-sectional behavioral assessments and geropathological analysis through organ harvesting at a standardized time point.

To estimate per-capita food consumption, two complementary methods were employed:

1. Initial population-based estimate: $\frac{Food\ remaining}{(Number\ of\ crickets\ on\ Day\ 1)(\ Days\ elapsed)}$
2. Final population-based estimate: $\frac{Food\ remaining}{(Number\ of\ crickets\ on\ Final\ Day)(\ Days\ elapsed)}$

Averaging these values yielded a balanced estimate that accounts for population mortality, ensuring accurate pre-cricket food consumption rates over the interval.

Behavioral Assays.

Y-maze. The Y-maze apparatus was designed with three arms oriented at 120° angles, converging at a central decision zone. Each arm measured 12 cm in length and 5 cm in width, dimensions optimized for cricket navigation based on prior research (Erregger et al., 2018; Madireddy & Madireddy, 2021). Maze walls were constructed to a height of 9 cm to prevent escape while allowing unobstructed exploratory behaviors during trials. Maze design was executed in OnShape, a parametric CAD software, ensuring precise geometric alignment and reproducibility. The 3D models were exported in STL format and processed using PrusaSlicer for slicing and G-code generation. Printing was conducted on a Prusa i3 MK3S+ 3D printer using 1.75 mm black polylactic acid (PLA) filament at a layer height of 0.2 mm to optimize resolution. Print settings included an infill density of 20% to balance structural integrity and material efficiency, with a bed temperature of 60°C and nozzle temperature of 215°C to ensure proper filament adhesion and layer bonding. A schematic of the Y-maze design is provided in Figure 3.

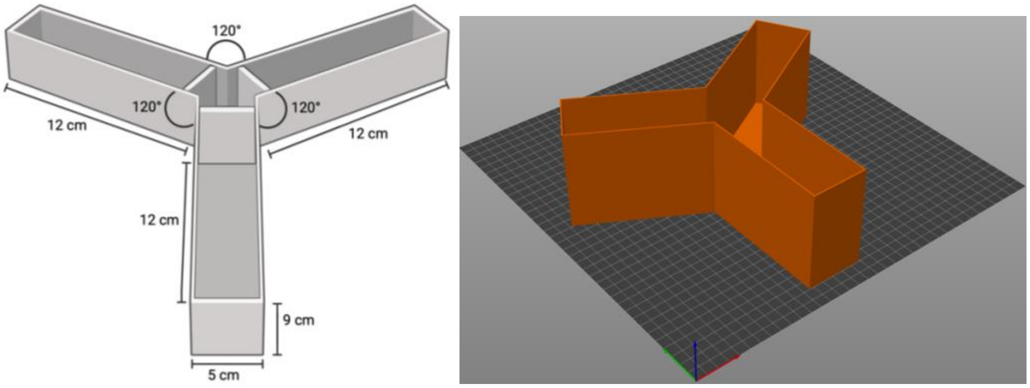


Figure 3. Schematic diagram of Y-maze constructed for cricket use, created using BioRender.com (left). Three-dimensional depiction of constructed Y-maze apparatus in OnShape (right).

The Y-maze is a widely used tool for assessing cognitive function across species, including humans (Cleal et al., 2021), rodents (Kraeuter et al., 2019), zebrafish (de Cognato et al., 2012; Cleal et al., 2023), and cricket (Erregger et al., 2018; Madireddy & Madireddy, 2021). Of the two common Y-maze paradigms, we implemented the continuous version, wherein subjects were placed in the center of the maze and allowed free exploration throughout the trial for 10 minutes. This approach minimizes confounding factors associated with rule learning, extensive handling, or repeated manipulations that can introduce variability (Sharma et al., 2010; Heredia-Lopez et al., 2016). Traditional interpretations of the Y-maze assess working memory through spontaneous alternation percentages, defined as consecutive entries into three different arms (Hughes 2004). However spontaneous alternation scores can be confounded by locomotor alterations, repetitive behaviors, or anxiety-driven novelty avoidance, limiting their reliability as measures of cognitive flexibility (Stewart et al., 2011). To address these limitations, we implemented a free-movement pattern (FMP) Y-maze approach, incorporating a nuanced data analysis framework (Cleal et al., 2021).

To extract movement patterns, navigational decisions were encoded as left (L) or right (R) turns. Behavioral sequences were segmented into overlapping tetragrams (four-choice sequences), yielding 16 possible tetragram combinations (Cleal et al., 2021). A two-choice guessing task framework was applied to quantify deviations from random exploration, enabling detection of complex movement patterns and decision-making (Frith & Done, 1983 Gross et al., 2011). Three key metrics were calculated to assess cognitive flexibility and behavioral stereotypy:

1. *Repetitive tetragrams as a proportion of total tetragrams.* The proportion of repetitive tetragrams, recurrent identical four-element sequences, was computed to quantify stereotyped behavioral patterns (Cleal et al., 2021). Increased repetitive tetragrams are indicative of reduced cognitive flexibility and an overreliance on habitual motor patterns, which have been associated with age-related cognitive decline. Normalization by total sequence production ensured differences were not confounded by individual variability in movement frequency. The metric was calculated as:

$$P_{repetitive} = \frac{Count\ of\ unique\ tetragrams\ occurring\ \geq 2\ times}{Total\ tetragrams\ observed} \quad \text{(Equation 1)}$$

For instance, in the sequence LLLL → RRRR → RLRL → RLLR, two tetragrams (LLLL and RRRR) would be classified as repetitive. If five total tetragrams were observed, the subject's repetitive tetragram proportion would be 0.4.

2. *Proportion between repetitive and varied tetragram transitions.* To evaluate the balance between habitual behavior and exploratory decision-making, we calculated the ratio of repetitive to varied tetragram transitions. A shift toward repetitive transitions suggests reduced cognitive flexibility, while a higher proportion of varied transitions indicates adaptability. The metric was computed as:

$$P_{repetitive/varied} = \frac{Number\ of\ repetitive\ transitions}{Number\ of\ varied\ transitions} \qquad \text{(Equation 2)}$$

A transition was considered repetitive if an identical tetragram followed (e.g., RRRR → RRRR), whereas a varied transition occurred when a different tetragram followed (e.g., RRRR → RLRL). For example, in the sequence RRRR → RRRR → RLRL → RLLR, two repetitive transitions and two varied transitions would yield a ratio of 1.0.

3. *Shannon's entropy calculation.* Shannon's entropy (H) was used to quantify exploratory variability, with higher values indicating greater behavioral diversity and lower values suggesting increased rigidity (Shannon & Weaver, 1964). Entropy measures have been widely applied in neuroscience and behavioral ecology to assess cognitive flexibility and decision-making processes (He et al., 2024; Grzywacz 2025; Viol et al., 2017). Reduced entropy has been associated with cognitive decline in both human and animal models, reflecting an increased dependence on habitual behaviors (Cipriani et al., 2013; Gallagher & Rapp 1997). Entropy was computed as:

$$H = -\sum p_i log_2 p_i \qquad \text{(Equation 3)}$$

where p_i represents the probability of occurrence of each unique tetragram. Behavioral sequences were first segmented into overlapping tetragrams, and the frequency of each tetragram was used to derive probability distributions. A decline in entropy for geriatric crickets, particularly in conjunction with increased repetitive tetragram sequences, would indicate reduced cognitive flexibility and a shift toward fixed behavioral routines, providing insight into age-related cognitive decline in an invertebrate model.

Workflow was conducted using Python 3.13.2.

Olfactory-guided decision-making in the y-maze paradigm. To investigate odor-driven decision-making and cognitive function, we employed the Y-maze paradigm with distinct olfactory cues. To create a controlled olfactory environment, one choice arm contained a vanilla odorant (1% vanilla extract, diluted 1:1 in distilled water), while the other contained a cinnamon odorant (1% cinnamon extract, diluted 1:1 in distilled water). Odorant selection was guided by prior evidence of differential olfactory responses in crickets. Vanilla was chosen as an attractive stimulus based on empirical observations demonstrating innate approach behavior toward vanilla-scented substrates in controlled preference assays (Scotto-Lomassese et al., 2003). In contrast, cinnamon was selected as a repellent stimulus, supported by reports from agricultural and pest-control literature describing reduced cricket activity in cinnamon-treated environments, as well as anecdotal accounts from horticultural forums suggesting its deterrent properties.

Each cricket was individually placed in the start arm and confined by a removable barrier for 10 seconds to allow acclimation. Upon barrier removal, the cricket was free to explore the maze for a maximum of 30 seconds. A choice was recorded when the cricket's entire body entered one of the two choice arms. Once a choice was made, the barrier was reintroduced to confine the cricket within the selected arm for 15 seconds, allowing continued exposure to the chosen odor. To assess whether crickets could reliably track their preferred odor, the odorant was repositioned to the alternate arm following each trial. This design enabled us to evaluate whether crickets demonstrated a path-chasing effect, indicative of odor discrimination and cognitive retention (Figure 4).

If a cricket failed to enter a choice arm within the allotted 30 seconds, the trial was excluded from analysis. Each cricket underwent a total of eight consecutive trials, with an inter-trial interval of 30 seconds to minimize residual olfactory cues from prior choices. The primary outcome measures were the percentage of entries into the vanilla-scented arm across trials to provide a quantifiable metric of odor preference and cognitive decision-making, while the time spent traveling to each arm was recorded to control for possible age-related motor deficits.

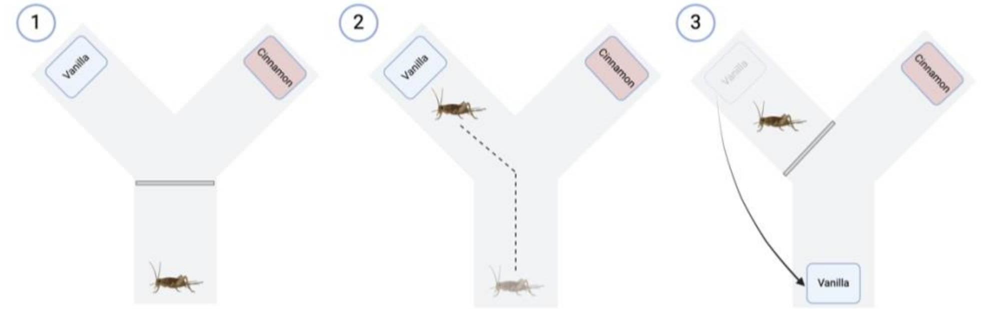


Figure 4. Schematic of scent preference test. Created using Biorender.com.

Open field test. To assess locomotion and anxiety/exploratory-related behaviors, crickets underwent a 5-minute open field test (OFT) in a dark environment. Each cricket was individually placed at the center and exploration was recorded for subsequent analysis (Figure 5). Between trials, the arena was thoroughly sanitized with 10% bleach to eliminate residual olfactory cues. This test provided dual-purpose evaluation by measuring spontaneous locomotion (Kiuchi et al., 2023) and anxiety/exploratory-related behaviors (Kraeuter et al., 2019; Soibam et al., 2012).

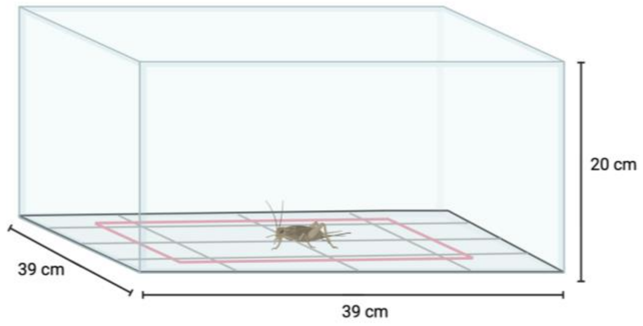


Figure 5. Schematic diagram of the open-field test. Figure created using Biorender.com.

All behavioral recordings were analyzed using ezTrack software (Pennington et al., 2019), a validated tool for automated location tracking and motion detection on par with commercial software (McElroy et al., 2020). Videos were uploaded into the software, and the arena dimensions were calibrated. Predefined regions of interest (ROI), central and peripheral zones, were manually assigned to quantify spatial preferences. ezTrack processed each video at 30 frames per second (FPS) and generated an output containing: positional coordinates of the cricket per frame, total distance traveled, and motion/freezing counts based on a predefined threshold (Figure 6).

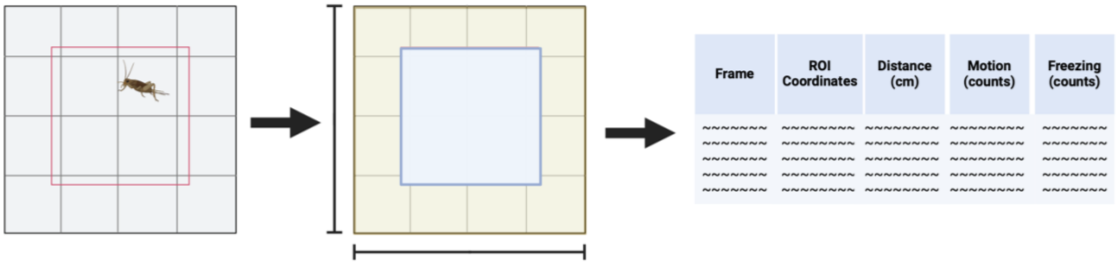


Figure 6. Schematic diagram of ezTrack software workflow. Figure created using Biorender.com.

From these outputs, we derived physiologically relevant endpoints for assessing exploratory behavior and anxiety. Our workflow began by categorizing subjects into their respective groups and filtering out spurious velocity readings, values that were physiologically implausible and likely artifacts of the detection system. We defined the upper threshold for valid velocities as the 99th percentile and exclude values exceeding this limit. Using these refined data, we extracted key behavioral parameters including central exploration (central zone entries per total entries), peripheral exploration (peripheral zone entries per total entries), freezing behavior (freezing episodes in both central and peripheral zones per total counts), and locomotion metrics (total distance traveled and average speed).

To differentiate walking from running, we applied a k-means clustering (k = 2) on velocity data for each group. This unsupervised learning approach effectively identified natural velocity groups without requiring predefined thresholds, ensuring an objective classification of walking vs. running. The cluster centers provided data-drive velocity cutoffs, reducing subjectivity and enhancing reproducibility. Cluster centers were used to define walking and running thresholds. This enabled further classification of walking parameters (total walking distance, time spent walking, average walking speed) and running parameters (total running distance, time spent running, average running speed). Additionally, we analyzed these locomotor behaviors within both the central and peripheral zones to better characterize exploratory behavior.

Workflow was conducted using Python 3.13.2.

Assessment of induced locomotion using a modified treadmill. To evaluate induced locomotion, we adapted an Exer 3/6 treadmill (Columbus instruments, Columbus, OH, USA), originally designed for rodent exercise studies, for crickets. Modifications included disabling the shock apparatus, installing custom dividers to prevent lateral escape, and implementing paper catch systems at the treadmill's starting zone (Figure 7). These modifications ensured that crickets unable to sustain running would land safely in a designated catch rather than exiting the apparatus, thereby maintaining standardized testing conditions.

To provide a species-specific motivational cue, a filter paper lined with pure vanilla extract was affixed at the treadmill's terminal end. This scent was selected based on prior findings demonstrating crickets' innate attraction to vanilla (Scotto-Lomassese et al., 2003). The treadmill was programmed with a fixed inclination of 0° and an acceleration rate of 0.1 m/s^2, ensuring a consistent ramp-up in speed while minimizing excessive stress.

To quantify locomotor performance, rulers were affixed along the treadmill's sidewalls to measure horizontal jump distance during trials. Each cricket underwent three independent trials, with the best performance recorded as the representative measure. Key metrics included maximum velocity (cm/s), total time spent running (s), maximum horizontal jump distance (cm).

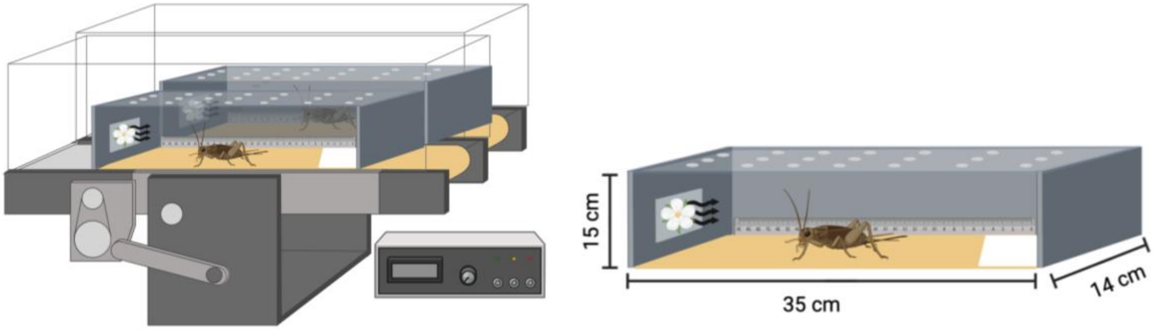


Figure 7. Schematic diagram detailing crickets completing the treadmill test with controller on bottom right (left). Dimensions of each individual compartment detailed (right). Figures created using Biorender.com.

Escape paradigm. Given that associative learning requires greater neural processing compared to spontaneous locomotor behaviors, implementing a cognitive demanding paradigm allows for a more robust assessment of age-related changes in learning efficiency. Here, we adapted an escape-based learning paradigm originally developed by Scotto-Lomassese et al., 2003, in which crickets were trained to associate olfactory cues with a favorable or unfavorable outcome.

To optimize the paradigm for motivation and minimize excessive stress, we refined both the reinforcement structure and task design. Instead of a generic large dimly lit chamber as a reward, we introduced a socially and thermally enriched environment to capitalize on crickets' innate drive for group cohesion and warmth-seeking behavior. Conversely, rather than subjecting crickets to an overly aversive punishment, we implemented a sensory-deprived, neutral isolation chamber, an approach that maintains a clear motivational contrast while preventing undue distress. Additionally, to ensure the safety of crickets falling into the punishment chamber, we reinforced the landing area with cotton balls, preventing injury upon descent. This design ensures that task engagement is driven by naturalistic decision-making, providing a robust framework for investigating cognitive aging in crickets while maintaining ethical considerations.

Crickets are highly social insects that rely on acoustic communication for mate attraction, competition, and group cohesion. Prior studies indicate that exposure to conspecific calls enhances locomotor activity and social aggregation (Hedwig & Stumpner 2016; Huber 1975), suggesting that social environments serve as a powerful natural reward. In our paradigm, successful task performance resulted in the cricket being transferred to a larger enclosure containing live conspecific calls, reinforcing their innate preference for group settings, and equipped with a heating pad to replicate thermally optimal conditions (29 ± 1°C). This multi-sensory reinforcement structure ensured that task success was linked to biologically relevant and ethologically valid stimuli.

In contrast, incorrect responses result in confinement to an acoustically and thermally neutral enclosure, devoid of conspecific sounds and lacking thermal gradients. Given that insects exhibit stress responses in socially isolated conditions (Lihoreau et al., 2009), removal from an enriched environment into an empty, ambient-temperature chamber provided a mild but ecologically meaningful form of negative reinforcement. Unlike traditional aversive conditioning methods that may induce excessive stress, this approach maintained ecological validity while still establishing a clear motivational contrast between correct and incorrect choices.

The escape paradigm was conducted within a circular arena featuring two escape holes (Figure 8). Each hole was associated with a distinct olfactory cue, either vanilla (a naturally preferred odor) or cinnamon (a naturally aversive odor). To introduce a cognitively demanding challenge, we implemented an inverse reinforcement strategy: the aversive cinnamon odor was paired with the rewarding environment, while the attractive vanilla odor led to isolation, with the odorants being lined in filer paper (1% vanilla extract, 1% cinnamon extract, diluted 1:1 in distilled water) placed 7 cm away from the holes. This design required crickets to override instinctual odor-driven behavior, thereby engaging higher-order cognitive processing.

To control for potential visual confounds, the arena was rotated by 45° between trials, ensuring that external cues did not inadvertently guide the crickets' decisions. All trials were conducted in a dark enclosure with a focused overhead light to standardize visual conditions. To enhance motivation, crickets were deprived of food for two days prior to testing, a method shown to increase engagement in learning tasks without inducing excessive stress (Scotto-Lomassese et al., 2003).

During the training phase, each cricket underwent ten trials per day for a maximum of five consecutive days. The first two trials were designed to familiarize the cricket with the task: only one escape hole was open per trial (randomly assigned to either the reward or punishment condition), ensuring that each individual experienced both outcomes before making independent choices. In the subsequent eight trials, both escape holes were accessible, requiring the cricket to actively choose between them. A choice was recorded when the cricket entered one of the holes completely. To quantify learning and decision-making efficiency, we measured 1) escape hole selection (reward vs. punishment) and 2) latency to decision (time taken to enter a hole). Latency served as an additional indicator of cognitive impairment, as longer decision times could reflect uncertainty or impairment in associative learning. Following each trial, crickets remained in their assigned reinforcement environment for six minutes before being returned to the arena for the next trial.

Crickets were considered to have successfully learned the task if they achieved a score of 7/8 or 8/8 correct choices in a single session, at which point they were removed from further training. If a cricket failed to meet this criterion after five days of testing, it was classified as a non-learner.

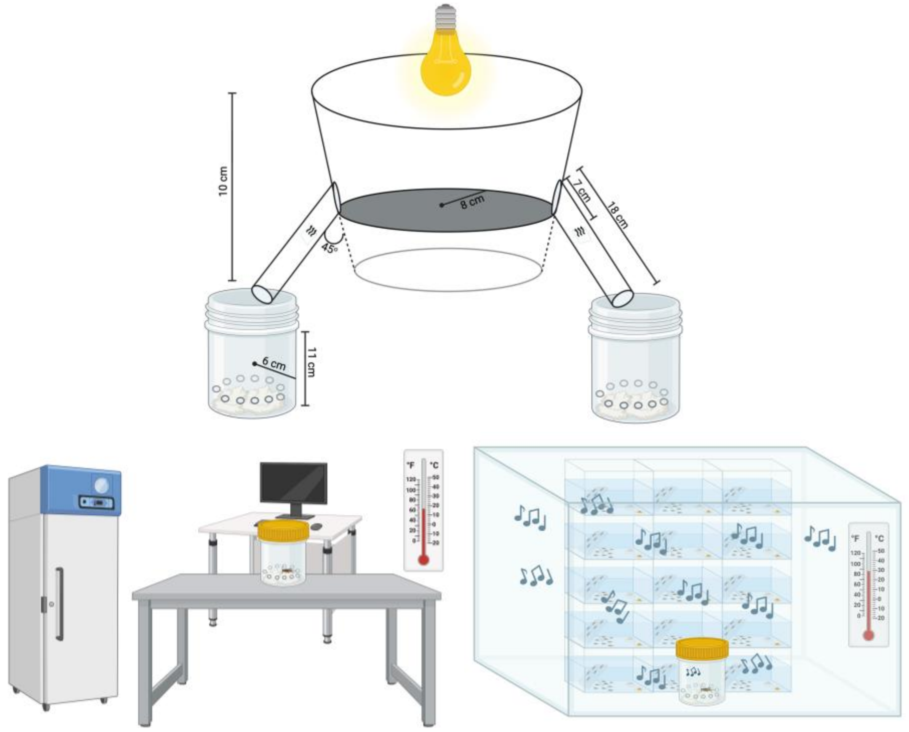


Figure 8. Schematic diagram of the escape paradigm (top). Schematic representations of the positive (right) and the negative (left) reinforcements. Figures created using BioRender.com

Given the rigorous nature of this experimental paradigm, which involved multiple testing days and repeated trials, we assessed physiological stress responses by monitoring changes in body weight. Weight loss has been implicated as a biomarker of stress-induced frailty and aging-related decline in humans (Mason et al., 2018; Miller and Wolfe, 2008). To evaluate whether crickets exhibited a similar response, all individuals were weighed at baseline on the first day of the experiment and again immediately prior to euthanasia following completion of the learning paradigm.

Due to the substantial time investment required of the experimenter and the considerable physical demands placed on the subjects, we ultimately excluded the escape paradigm from our drug intervention testing pipeline. Although this assay offers valuable insight into learning and memory processes, particularly in distinguishing cognitive capacities across adult, mid-age, and geriatric cohorts, its complexity and labor-intensive nature render it impractical for high-throughput or large-scale pharmacological screening. We present the results of this assay here to highlight its utility in probing age-related cognitive decline but acknowledge that its implementation is not conducive to the goal of developing an accessible, scalable, and globally adoptable platform for anti-aging drug testing.

Euthanasia and Sample Preparation. To ensure rapid and humane euthanasia, crickets were exposed to carbon dioxide (CO_2) in a controlled chamber and subsequently decapitated as an adjunctive method following AVMA guidelines (Leary et al., 2020). Post-mortem assessments were conducted immediately after euthanasia to prevent degradation-related artifacts in morphometric and histological analyses. Heads were detached at the cranio-cervical junction, and hind legs were removed at the coxa-trochanter junction. Each tissue type was placed in separate labeled cassettes and fixed in Bouin's solution for 72 hours. This duration and type of fixation was empirically determined to best preserve internal structures and minimize gut extrusion during subsequent dissection (unpublished observations). Following fixation, bodies were bisected longitudinally to expose internal organs while maintaining anatomical integrity. For long-term preservation prior to paraffin embedding, tissues were transferred to a 1:1:1 solution of n-butyl alcohol, isopropyl alcohol, and deionized water and stored at room temperature until processing.

Statistical Analysis. Group-level characteristics were summarized using standard descriptive statistics. Categorical variables were expressed as counts and percentages (n [%]) and compared using χ^2 analysis or Fisher's exact test when $\leq$ 80% of cells contained $n \leq 5$, with effect sizes reported as relative risk (RR) with 95% confidence intervals (CIs). For instances involving zero counts, a continuity correction was applied using the modified Haldane-Anscombe correction (Weber et al., 2020) to ensure robust estimation of effect sizes. Continuous variables were reported as means with standard deviations (SD) and analyzed using one-way analysis of variance (ANOVA), with effect sizes calculated as either Cohen's *d* or with Hedges' *g* correction (*d*) to account for small sample bias (Cohen 2013, Taylor & Alanazi 2023). Confidence intervals for effect sizes of continuous variables were computed using a standardized effect size calculator (Coe 2023).

All data were stratified by age and sex or treatment group and sex prior to analysis. Data distribution was assessed using the Shapiro-Wilk test to evaluate normality, with exceptions made for sufficiently large sample sizes (N > 30), where normality was assumed in accordance with the central limit theorem. Parametric tests were applied to normally distributed data, while non-normally distributed data were analyzed using non-parametric methods.

To evaluate group-level differences across age or treatment conditions, a one-way ANOVA was employed when groups were normally distributed and a Kruskal-Wallis test when groups were non-normally distributed. Tukey's post-hoc test was used for age group comparisons, while Dunnett's test was applied when comparing treatment groups to a control or specific reference age group. Two-way ANOVA was performed to assess main and interactive effects of age (or treatment) and sex. In cases where interaction terms were not statistically meaningful, but a main effect was observed, post hoc comparisons were conducted using Bonferroni-adjusted tests for within-group sex comparisons, and Tukey's or Dunnett's tests for between-group comparisons within each sex to maintain family-wise error control.

In behavioral assays aimed at distinguishing between walking and running activity, an unsupervised machine learning approach was implemented using k-means clustering (k = 2) to classify locomotor behavior based on velocity data. Clustering performance was validated using silhouette scores and visual inspection of cluster separation. The resulting behavioral classifications were subsequently used in downstream inferential analyses described above.

Survival analyses were conducted to evaluate the effects of pharmacological treatment and group-level food consumption on longevity. Kaplan-Meier survival curves were generated to visualize survival distributions across experimental groups, with median lifespan (in days) reported for each cohort. Group-wise comparisons were assessed using the log-rank (Mantel-Cox) test. To model covariate-adjusted differences in survival, a Cox proportional hazards regression model was fitted, treating survival time as the dependent variable and death as the event of interest. Independent variables included categorical indicators for treatment group (with the control group as the reference), group-level food consumption, and interaction terms between food consumption and each treatment group. This structure permitted the estimation of both main effects and treatment-specific modulation by nutritional intake. Prior to model inclusion, all covariates were evaluated for multicollinearity using variance inflation factors and condition indices. Sex was included as an additional covariate to account for potential sex-based differences in survival. Hazard ratios (HRs) with associated *P*-values were calculated, and multiple comparisons were corrected using the Benjamini-Hochberg to control the False Discovery Rate (FDR).

All statistical analyses were performed using GraphPad Prism version 10.0.3 (GraphPad Software) or Python version 3.13.1 (Python Software Foundation). Inferential statistics were conducted with the SciPy library version 1.13.1 and machine learning algorithms were implemented using scikit-learn (Pedregosa et al., 2011). Graphical representations were generated with either matplotlib version 3.9.2 or GraphPad Prism. Statistical significance was defined as $\alpha = 0.05$.

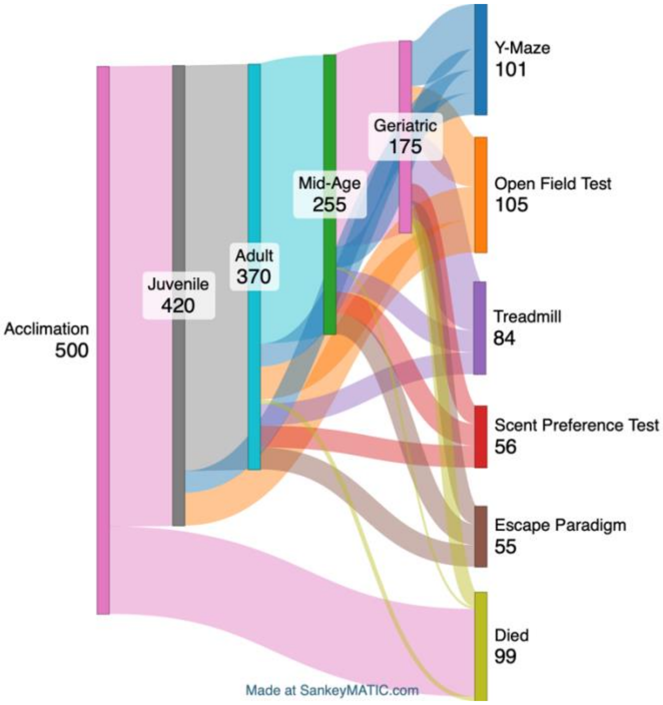
Power Analysis for Lifespan Studies. To ensure adequate statistical power to detect clinically relevant differences in lifespan among cricket cohorts, power analysis was conducted based on pilot studies. Preliminary data from the pilot study, which included 100 crickets (50 males, 50 females) distributed across control (n = 20) and treatment groups (n = 20 each), indicated mean lifespans of 17.30 days (SD = 12.22) in the control group (corresponding to a mean age of 59.30 days) and 25.00 days (SD = 17.03) in the combined treatment groups (mean age of 67.03 days). Using these pilot data, a power analysis was performed employing a two-sided two-sample t-test with a significance level (α) of 0.05. The analysis determined that a sample size of 60 crickets per group would provide 80% power to detect a statistically significant difference in lifespan (Soper 2013). To account for potential mortality during the acclimation period and to enhance robustness, 100 crickets per group (N = 400) were included in the final experimental design. For sex-specific analyses, pilot data revealed mean lifespans of 13.10 days (SD = 13.45) for males in the control group compared to 24.07 days (SD = 16.74) in the treated group. In females, the mean lifespan was 17.50 days (SD = 10.55) in the control group and 26.93 days (SD = 17.55) in the treated group. Sex-specific power analyses indicated that sample sizes of 32 males and 39 females per group would provide 80% power to detect differences at a significance level of 0.05 (Soper 2013). To increase the robustness of the study and mitigate the impact of early mortality, 50 crickets of each sex per group were included prior to the 1-week acclimation period.

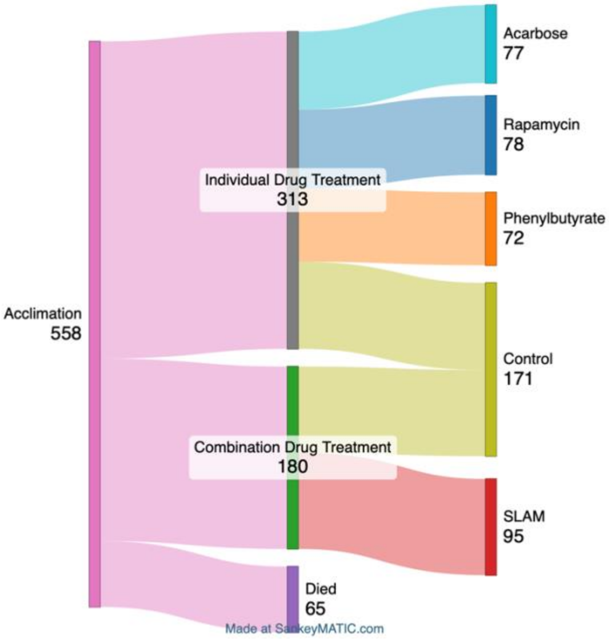
Results.

Experimental cohorts were well-matched for sex distribution across all assays.

Experiments were conducted between June 25th, 2024, and April 23rd, 2025. A total of 313 crickets were included in the lifespan assay evaluating individual drug treatments, divided among control (N = 86), acarbose (N = 77), rapamycin (N = 78), and phenylbutyrate (N = 72) groups. Sex distributions were balanced across cohorts, with males comprising 39.5% in controls, 46.8% in acarbose, 47.4% in rapamycin, and 45.8% in phenylbutyrate (*RR*'s = 1.12 to 1.15, *P*'s = 0.31 to 0.43).

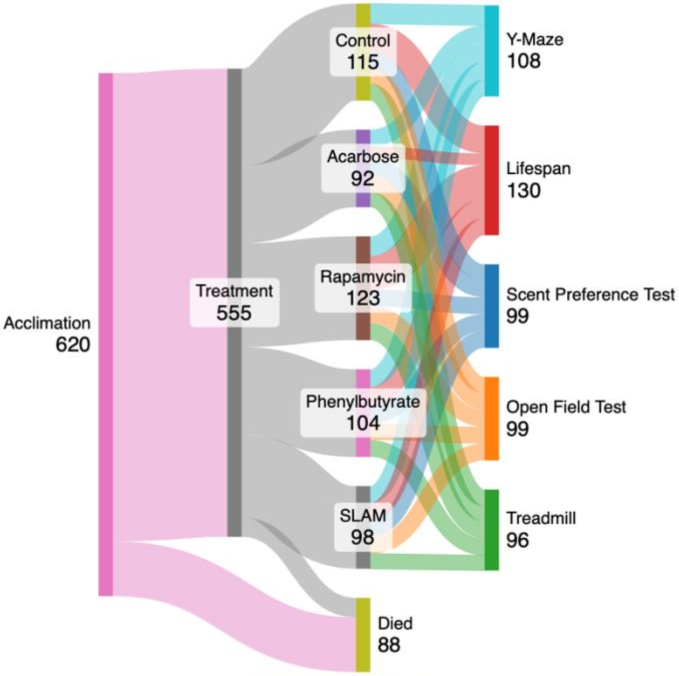
For the lifespan assay evaluating combination treatment, 180 crickets were analyzed between control (N = 85) and SLAM (N = 95) groups. Male and female proportions were nearly identical (50.6% male in controls vs. 50.5% male in SLAM-treated; *RR* = 1.00 [95% CI: 0.75 to 1.35], *P* = 0.99).





For the age-stratified cohorts, in the Y-maze behavioral assay, a total of 101 crickets were analyzed across four age groups: juvenile (N = 20), adult (N = 21), mid-age (N = 19), and geriatric (N = 41). Male representation ranged from 55.0% to 63.2%, with no statistically detectable sex differences among groups (P = 0.95). In the scent preference test (N = 56), adult, mid-age, and geriatric groups each included an equal 50.0% male representation, showing no variation across age cohorts (P > 0.99). For the open field test (N = 105), the juvenile (N = 30), adult (N = 30), and geriatric (N = 45) groups displayed balanced sex ratios, with male proportions between 50.0% and 53.3% (P = 0.94). Similarly, in the treadmill assay (N = 84), sex ratios were comparable across adult (N = 20), mid-age (N = 20), and geriatric (N = 44) groups, with males comprising 47.7% to 55.6% of each cohort (P = 0.98). In the escape paradigm (N = 55), sex distributions remained consistent across adult (N = 20), mid-age (N = 19), and geriatric (N = 16) groups, with no observed differences (P = 0.98).

In treatment-stratified cohorts, for the Y-maze assay, 108 crickets were divided among treatment groups including control (N = 24), acarbose (N = 20), rapamycin (N = 23), phenylbutyrate (N = 21), and SLAM (N = 20). Male representation ranged from 47.6% to 60.9%, with no significant differences compared to the control group (relative risks \[RR] = 0.62 to 0.80; P = 0.11 to 0.47). For the scent preference test (N = 99), treatment groups included control (N = 19), acarbose (N = 20), rapamycin (N = 20), phenylbutyrate (N = 20), and SLAM (N = 20), with male proportions ranging from 45.0% to 50.0%. No differences in sex distribution were found relative to controls (RR = 0.57 to 0.64; P = 0.13 to 0.22). In the open field test (N = 99), sex ratios across control, acarbose, rapamycin, phenylbutyrate, and SLAM groups (Ns = 19–20 each) were also comparable (RR = 0.90 to 1.13; P = 0.73 to >0.99). Likewise, in the treadmill assay (N = 96), control (N = 20), acarbose (N = 18), rapamycin (N = 20), phenylbutyrate (N = 20), and SLAM (N = 18) groups showed no detectable differences in male representation (RR = 0.90 to 1.13; P = 0.73 to >0.99).



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A full breakdown of experimental dates (MM/DD/YYYY) and detailed sex comparisons for each cohort is provided in Appendix 1.

Morphological measures were excluded as covariates to avoid overfitting and due to lack of treatment effects. Body size and proportional measurements were evaluated across treatment groups to assess whether somatic variation could confound behavioral outcomes, as prior observations have shown age-related and sex-dependent changes in these traits in house crickets (Liao et al., 2025). Across both overall and sex-stratified datasets, no treatment-related differences were observed for key morphological traits, including body weight, body length, antennal length, hind leg length, femoral cross-sectional area, femoral volume, and femoral surface area-to-volume ratio. Similarly, no differences emerged for proportional scaling relationships (hind leg length to body length, antennal length to body length, hind leg length to weight, body length to weight) or sensory to limb scaling ratios (hind leg length to antennal length, antennal length to weight) (*P*'s < 0.05).

Inclusion of these somatic parameters as covariates in behavioral analyses was therefore not pursued, as doing so would have risked overfitting, artificially inflating model complexity without improving explanatory power. Overfitting would not only compromise statistical validity but also reduce generalizability across cohorts, particularly given the modest sample sizes inherent to high-resolution behavioral studies. Accordingly, behavioral analyses focused on treatment effects without adjustment for morphometric parameters.

Within-group comparisons between females and males, by contrast, revealed consistent sex differences in multiple somatic parameters, particularly weight, body length, and proportionality measures (*P*'s < 0.05). However, our primary objective was to assess treatment effects on behavior independent of sex-specific morphometric variation. Accordingly, while sex differences in somatic measures were documented and presented in the appendix for transparency, they were not incorporated into the behavioral models to maintain analytic focus and avoid introducing covariates not directly relevant to treatment efficacy.

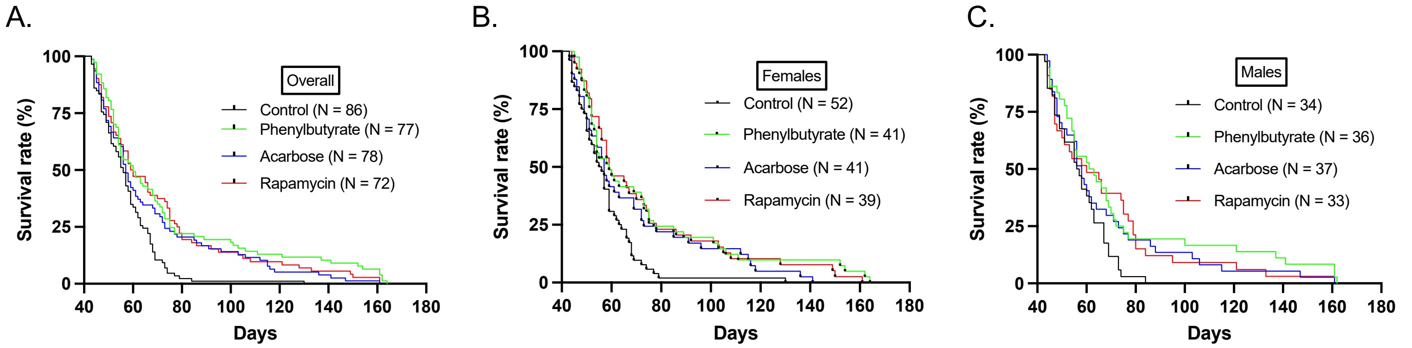
Detailed results, including descriptive statistics, effect sizes, and adjusted *P*-values, are presented in Appendix 2. Two supplementary tables summarize (1) treatment group comparisons and (2) within-group female versus male comparisons across all body measurements.

Phenylbutyrate, rapamycin, and acarbose extended lifespan independently of food consumption, with greater survival observed in females. To evaluate the efficacy of individual geroprotective compounds on lifespan, we compared survival outcomes among crickets treated with phenylbutyrate (PBA), rapamycin (RAP), and acarbose (ACB). All three treatments prolonged lifespan relative to controls (median: 56 days) (Figure 9A). Phenylbutyrate treatment resulted in the greatest increase in median survival (60 days; *HR* = 0.50 [95% CI: 0.35, 0.70], *P* < 0.0001), followed by rapamycin (59.5 days; *HR* = 0.50 [95% CI: 0.36, 0.71, *P* < 0.0001), and acarbose (57 days; *HR* = 0.61 [95% CI: 0.44, 0.85], *P* = 0.011).

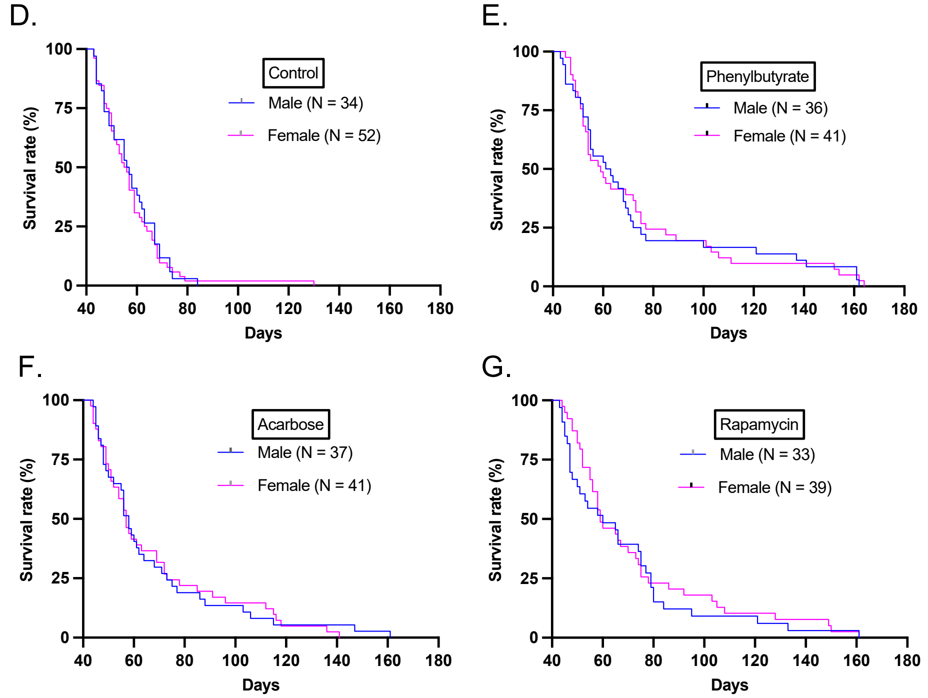
Stratified analyses by sex indicated that the survival benefits of rapamycin and phenylbutyrate were primarily driven by female crickets. Among females, median survival increased from 55.5 days in controls to 59.0 days in both the phenylbutyrate and rapamycin groups (*HR* = 0.50 [95% CI: 0.32, 0.78], *P* = 0.0072 and *HR* = 0.50 [95% CI: 0.32, 0.788], *P* = 0.0063, respectively). Acarbose-treated females also showed a slight increase in lifespan to 57.0 days (*HR* = 0.61 [95% CI: 0.39, 0.95, *P* = 0.082) (Figure 9B). In contrast, males exhibited more variable outcomes (Figure 9C). While phenylbutyrate slightly extended male survival from 56.5 to 62.0 days (*HR* = 0.53 [95% CI: 0.31, 0.89], *P* = 0.051), no benefits were observed for rapamycin- (*HR* = 1.06 [95% CI: 0.66, 1.71], *P* = 0.063) and acarbose-treated males (*HR* = 0.62 [95% CI: 0.37, 1.03], *P* = 0.20). Within-group sex comparisons showed no sex-based differences in survival across any of the groups (*HR*'s = 0.94 to 1.15, *P*'s = 0.57 to 0.96) (Figures 9D to 9G).

To determine whether survival benefits associated with drug treatment were attributable to differences in nutritional intake, a Cox proportional hazards model was fitted with treatment group, sex, group-level food consumption, and treatment x food interaction terms as covariates. After adjustment, both rapamycin (*HR* = 0.11 [95% CI: 0.034, 0.33], *P* < 0.0001) and phenylbutyrate (*HR* = 0.13 [95% CI: 0.043, 0.38], *P* < 0.0001) maintained strong protective effects on survival relative to controls. Acarbose was associated with a nonsignificant trend toward improved survival (*HR* = 0.42 [95% CI: 0.16, 1.09], *P* = 0.073).

Food consumption alone did not influence survival in the control group (HR = 0.67 [95% CI: 2.2×10^{-11}, 2.04×10^{10}], *P* = 0.97). Interaction terms revealed that food enhanced the survival benefit in the rapamycin (HR = 1.82×10^{43} [95% CI: 2.45×10^{15}, 1.35×10^{71}], *P* = 0.0016) and phenylbutyrate (HR = 8.23e21 [95% CI: 4.58, 1.48×10^{43}], *P* = 0.043) treated groups, while the acarbose x food interaction remained nonsignificant (HR = 16.19 [95% CI: 1.77×10^{-15}, 1.48×10^{17}], *P* = 0.88). Regarding sex, females exhibited a trend toward lower mortality (HR = 0.82 [95% CI: 0.66, 1.03], *P* = 0.091) compared to males.



Group	Overall			Female			Male		
	Survival (days)	*HR* (95% CI)	*P*-value	Survival (days)	*HR* (95% CI)	*P*-value	Survival (days)	HR (95% CI)	*P*-value
Control	56	Reference		55.50	Reference		56.50	Reference	
PBA	60	0.50 (0.35, 0.70)	<0.0001	59.00	0.50 (0.32, 0.78)	0.0072	62.00	0.53 (0.31, 0.89)	0.051
ACB	57	0.61 (0.44, 0.85)	0.011	57.00	0.61 (0.39, 0.95)	0.082	58.00	0.62 (0.37, 1.03)	0.20
RAP	59.5	0.50 (0.36, 0.71)	<0.0001	59.00	0.50 (0.32, 0.78)	0.0063	56.50	1.06 (0.66, 1.71)	0.063



	Control		Phenylbutyrate		Acarbose		Rapamycin	
	Male	Female[1]	Male	Female	Male	Female[1]	Male	Female
Survival (days)	56.50	55.50	62.00	59.00	56.50	55.50	62.00	59.00
HR (95% CI)	0.94 (0.60, 1.48)		1.03 (0.67, 1.64)		0.99 (0.62, 1.57)		1.15 (0.71, 1.87)	
P -value	0.80		0.89		0.96		0.57	

[1] Reference groups for effect size estimations and statistical testing.

Figure 9. Survival curves of treatment groups. Kaplan-Meier survival curves illustrating the median survival of crickets across control, phenylbutyrate, acarbose, and rapamycin treatment groups in the **(A)** overall, **(B)** female, and **(C)** male populations. All treatment groups showed

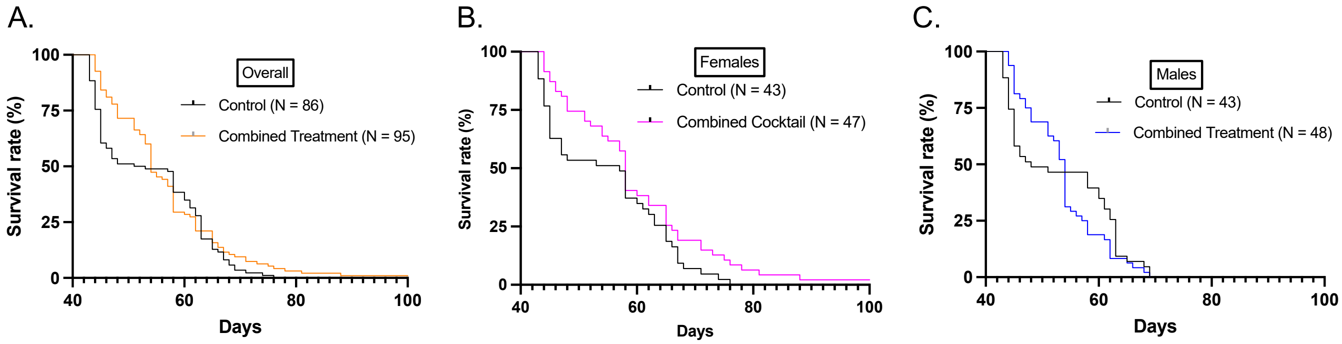
extended survival compared to the control group in the overall population while phenylbutyrate and rapamycin treated females showed extended survival compared to the control group. No within-group sex differences were observed in **(D)** control, **(E)** phenylbutyrate-, **(F)** acarbose-, or **(G)** rapamycin-treated groups.

SLAM treatment extends early survival in house crickets, with enhanced longevity in females. To evaluate the effects of combined rapamycin, acarbose, and phenylbutyrate (SLAM) treatment on longevity, we compared survival distributions between treatment and control groups at key survival thresholds (50%, 25%, and 0%). SLAM treatment conferred a pronounced survival advantage at the early phase of the lifespan curve, with a 50% survival median of 48 days compared to 45 days in controls ($HR = 0.37$ [95% CI: 0.23, 0.60], $P < 0.0001$) (Figure 10A). However, this early advantage was not sustained over time. By the 25% and 0% survival thresholds, median survival in treated crickets exceeded controls (53 days vs. 45 days and 54 vs. 52 days, respectively), but these differences were not statistically supported (HR: 0.96 [95% CI: 0.69, 1.35], $P = 0.80$ and $HR = 0.84$ [95% CI: 0.62, 1.12], $P = 0.19$, respectively).

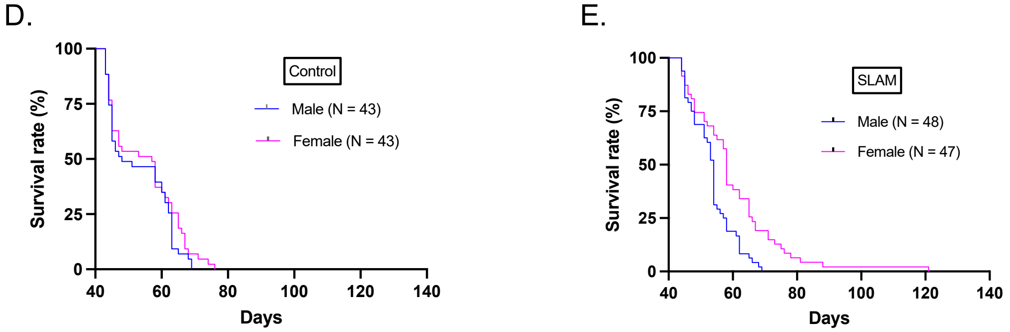
Sex-stratified analyses revealed that SLAM-mediated longevity benefits were similar in female and males. Female crickets in the treatment group survived longer than controls at earlier thresholds (Figure 10B). At the 50% survival point, median survival extended from 45 to 49.5 days ($HR = 0.42$ [95% CI: 0.22, 0.80], $P = 0.0004$), while no differences were observed at the 25% threshold (56 vs. 47 days; $HR = 0.67$ [95% CI: 0.41, 1.09], $P = 0.06$) or the 0% threshold (58 vs. 57 days; $HR = 0.69$ [95% CI: 0.45, 1.06], $P = 0.06$). Males exhibited a similar pattern, with treated males living longer than controls at the 50% threshold (47.5 vs. 44.5 days; $HR = 0.38$ [95% CI: 0.20, 0.74], $P < 0.0001$), but not at the 25% (51.5 vs. 45 days; $HR = 1.12$ [95% CI: 0.70, 1.80], $P = 0.55$) or 0% survival thresholds (54 vs. 48 days; $HR = 1.13$ [95% CI: 0.75 to 1.71], $P = 0.50$) (Figure 10C).

Within-group sex analyses demonstrated that while no differences were exhibited in the control group, treated females had longer lifespans than males. While no sex differences were observed within control animal across all thresholds (HR's = 1.15 to 1.31, P's = 0.24 to 0.53) (Figure 10D), treated females lived longer than their male counterparts at every survival checkpoint (Figure 10E). Median survival times were consistently longer for females (49.5 vs. 47.5 days at 50%, $HR = 1.72$ [95% CI: 0.96, 3.09], $P = 0.026$; 56 vs. 51.5 days at 25%, $HR = 2.08$ [95% CI: 1.27, 3.40], $P = 0.0001$; 58 vs. 54 days at 0%, $HR = 1.85$ [95% CI: 1.21, 2.81], $P = 0.001$).

To evaluate whether survival differences between treatment groups could be explained by food consumption, a Cox proportional hazards regression model was fitted. Combined treatment was associated with a lower hazard of death compared to control (HR = 1.52 [95% CI: 1.08, 2.14], $P = 0.02$). Male sex was independently associated with increased mortality risk compared to females (HR = 1.79 [95% CI: 1.30, 2.46], $P = 0.0003$). The main effect of food consumption trended toward increased hazard (HR = 1.54×10^{22} [95% CI: 0.12, 2.01×10^{45}], $P = 0.06$). A significant interaction between treatment group and food consumption was detected (HR = 2.52×10^{-31} [95% CI: 1.60×10^{-55}, 3.97×10^{-7}], $P = 0.013$), while no interaction was found between sex and food (HR = 1.07×10^{4} [95% CI: 4.41×10^{-19}, 2.59×10^{26}], $P = 0.72$).



Survival Rate	Group	Overall			Female			Male		
		Survival (days)	*HR* (95% CI)	*P*-value	Survival (days)	*HR* (95% CI)	*P*-value	Survival (days)	*HR* (95% CI)	*P*-value
50%	Control	45	Reference		45	Reference		44.5	Reference	
	Treatment	48	0.37 (0.23,0.60)	**<0.0001**	49.5	0.42 (0.22,0.80)	**0.0004**	47.5	0.38 (0.20,0.74)	**<0.0001**
25%	Control	45	Reference		47	Reference		45	Reference	
	Treatment	53	0.96 (0.69,1.35)	0.80	56	0.67 (0.41,1.09)	0.06	51.5	1.12 (0.70,1.80)	0.55
0%	Control	52	Reference		57	Reference		48	Reference	
	Treatment	54	0.84 (0.62,1.12)	0.19	58	0.69 (0.45,1.06)	0.06	54	1.13 (0.75,1.71)	0.50



	50% Survival Rate			25% Survival Rate			0% Survival Rate		
	Days	*HR* (95% CI)	*P*-value	Days	*HR* (95% CI)	*P*-value	Days	*HR* (95% CI)	*P*-value
Control									
Female[1]	45	1.31 (0.72,2.39)	0.24	47	1.15 (0.71,1.86)	0.53	57	1.23 (0.81,1.89)	0.28
Male	44.5			45			48		
Treatment									
Female[1]	49.5	1.72 (0.96,3.09)	**0.026**	56	2.08 (1.27,3.40)	**0.0001**	58	1.85 (1.21,2.81)	**0.001**
Male	47.5			51.5			54		

[1] Reference groups for effect size estimations and statistical testing.

Figure 10. Survival curves of combined treatment vs control groups. Kaplan-Meier survival curves illustrating the median survival of crickets across combined treatment and control groups at the 50%, 25%, and 0% survival rates for **(A)** overall, **(B)** female, and **(C)** male populations as well as for within-group sex differences between **(D)** control and **(E)** treatment groups. Overall and sex-specific treated group showed extended survival at the 50% survival rate compared to the control group. Treated females exhibited increased lifespan compared to males across the 50%, 25%, and 0% survival rates.

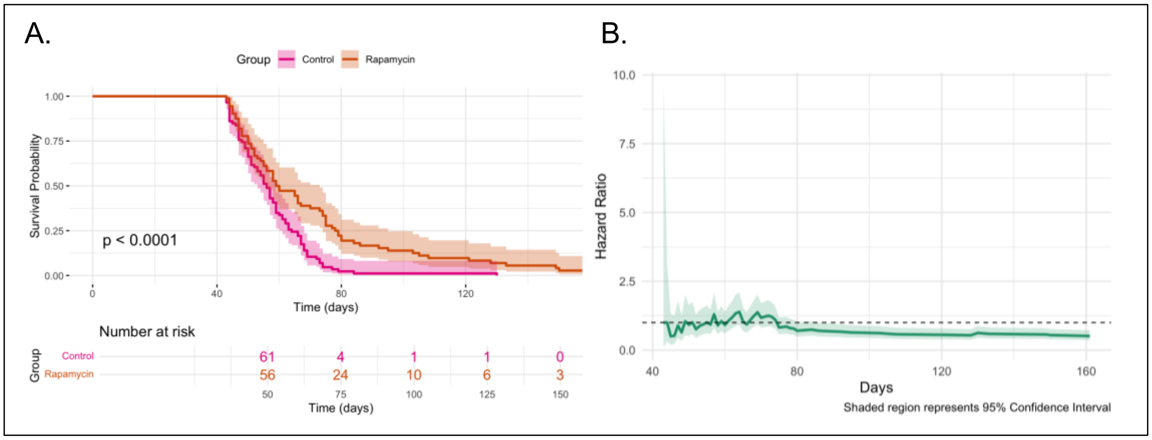
Statistical determination of intermittent drug treatment duration. To determine the onset and duration of differences among drug treatment groups, we performed a detailed analysis examining when survival disparities first emerged and how long they persisted. This analysis, crucial for defining the treatment duration in cross-sectional studies, involved comparing each treated group (rapamycin, acarbose, phenylbutyrate, and combined treatment) individually against control cohorts. We calculated cumulative hazard ratios (HRs) starting from the first day of treatment until all crickets were deceased, identifying intervals during which statistically significant survival differences between groups were observed.

Significance was defined as an HR consistently below or above 1, with a 95% confidence interval (CI) that did not include 1. To ensure robust statistical inference, we applied the Bonferroni correction to account for multiple comparisons.

Our findings demonstrated that the rapamycin-treated group exhibited a significant survival difference starting at 92 days (50 days after initial treatment), which persisted for the remainder of the study (Figures 11A and 11B). For the acarbose-treated group, the first significant difference appeared at Day 112 (70 days after initial treatment) and was sustained thereafter (Figures 11C and 11D). The phenylbutyrate-treated group showed a significant difference from Day 101 (59 days after initial treatment) onwards (Figures 11E and 11F). In contrast, the combined treatment group exhibited an early significant difference between Days 48 and 58 (6–16 days after initial treatment), but this effect was not sustained over the long term (Figures 11G and 11H).

Given that drug treatment was initiated in adult crickets, and our cross-sectional studies were intended to conclude at a geriatric age (10 weeks), our objective was to determine an optimal treatment duration that would capture differences in behavior at geriatric stages. The decision to select a treatment duration of 14 days was driven by both statistical and biological reasoning. Statistically, this interval aligned with the earliest observed window of sustained significance in the combined treatment group, allowing for the capture of early intervention effects without overextending into periods of potential confounding age-related decline. Biologically, this duration was deemed sufficient to induce measurable physiological changes without surpassing the crickets' adaptive response threshold. This data-driven approach ensures that the selected treatment duration reflects a biologically relevant window of intervention efficacy while minimizing the risk of diluting observed effects in subsequent cross-sectional analyses.

Detailed data and additional statistical analyses are presented in Appendix 3.



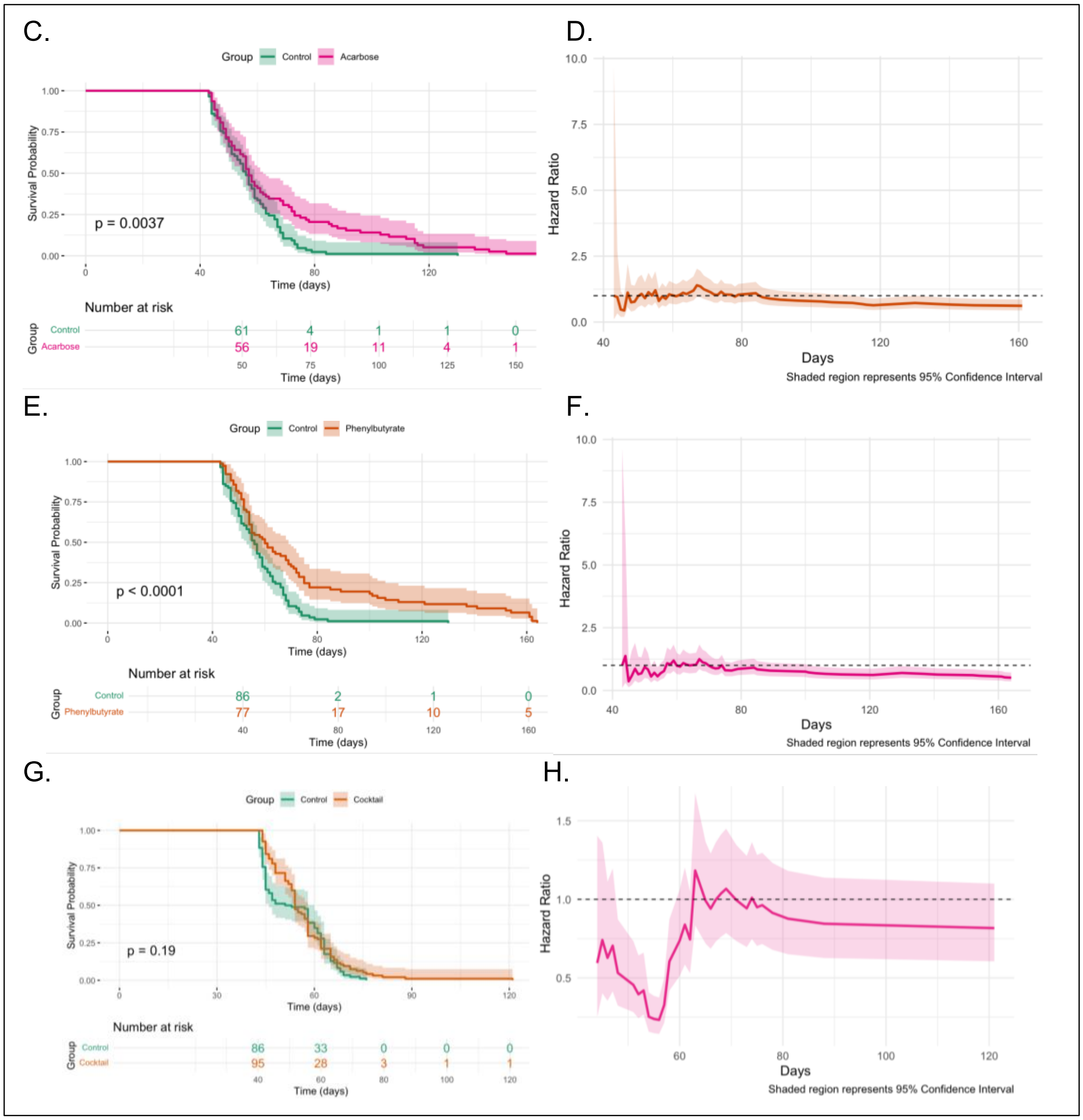
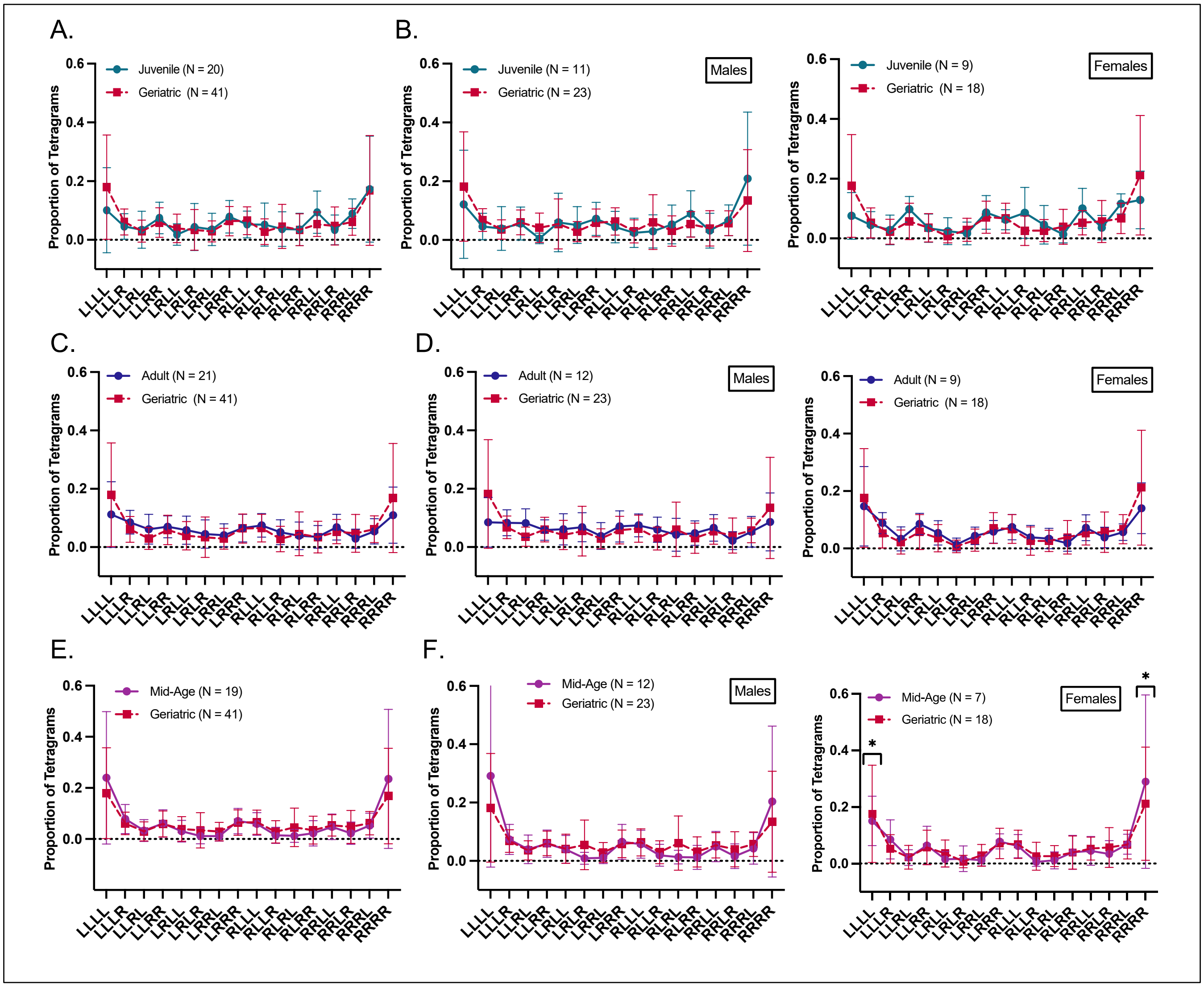


Figure 11. Time dependent onset and duration of survival benefits. (A, C, E, G) Kaplan-Meier survival curves (B, D, F, G) Hazard ratios over time (A-B) Rapamycin treatment prolonged survival 50 days post-treatment and was sustained throughout the remainder of the study. **(C-D)** Acarbose treatment extended lifespan 70 days post-treatment and was maintained until the study's end. **(E-F)** Phenylbutyrate treatment showed survival benefits starting at 59 days post-treatment and persisted throughout the study duration. **(G-H)** Combined treatment exhibited an early survival difference 6-16 days post-treatment, but the effect was not sustained long-term.

Repetitive behavior patterns are moderately influenced by age but not treatment.

Contrary to expectations of progressive behavioral rigidity with age, the proportion of repetitive tetragrams in the Y-maze did not differ between geriatric crickets and other age groups (juvenile: 0.31 ± 0.27; adults: 0.22 ± 0.13; mid-aged: 0.39 ± 0.28; geriatric: 0.32 ± 0.23; *d*'s = -0.50 to 0.27, *P*'s = 0.069 to 0.94; Figures 12A, 12C, 12E). However, stratifying by sex revealed age-dependent nuances. Among females, mid-aged crickets (0.49 ± 0.22) exhibited higher repetitive tetragram use than geriatric females (0.32 ± 0.25; *d* = 0.73 [95% CI: 0.01, 1.45], *P* = 0.039) (Figure 12F). Juvenile (0.33 ± 0.30) and adult females (0.17 ± 0.12) did not differ from geriatrics (*d*'s = -0.67 to 0.06; *P* = 0.075 to 0.88). In males, none of the age groups (juvenile: 0.29 ± 0.24; adult: 0.21 ± 0.14; mid-aged: 0.51 ± 0.27) differed from geriatrics (0.29 ± 0.22; *d*'s = -0.42 to 0.88, *P*'s = 0.090 to 0.66; Figures 12B, 12D). No sex differences were detected within any age group (*d*'s = -0.14 to 0.33, *P*'s = 0.43 to 0.85).

Treatment with acarbose (0.30 ± 0.17), rapamycin (0.28 ± 0.27), phenylbutyrate (0.29 ± 0.20), or SLAM (0.34 ± 0.18) did not alter the proportion of repetitive tetragrams compared to controls (0.30 ± 0.29; *d*'s = -0.06 to 0.15, *P*'s = 0.28 to 0.79; Figure 12G). Female-specific analysis showed consistency across groups (0.32–0.36), with minimal deviations from control females (*d*'s = –0.06 to 0.04, *P*'s = 0.62 to 0.91; Figure 12H). Male treatment groups also showed negligible effects (*d*'s = –0.36 to 0.33, *P*'s = 0.32 to 0.88). No within-treatment sex differences were detected (*d*'s = –0.74 to 0.05, *P*'s = 0.51 to 0.95).



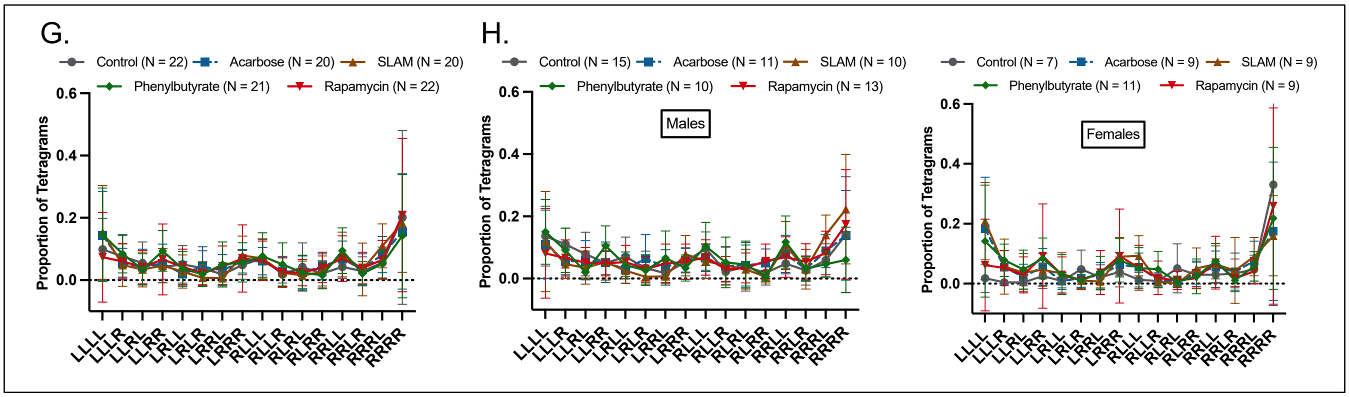
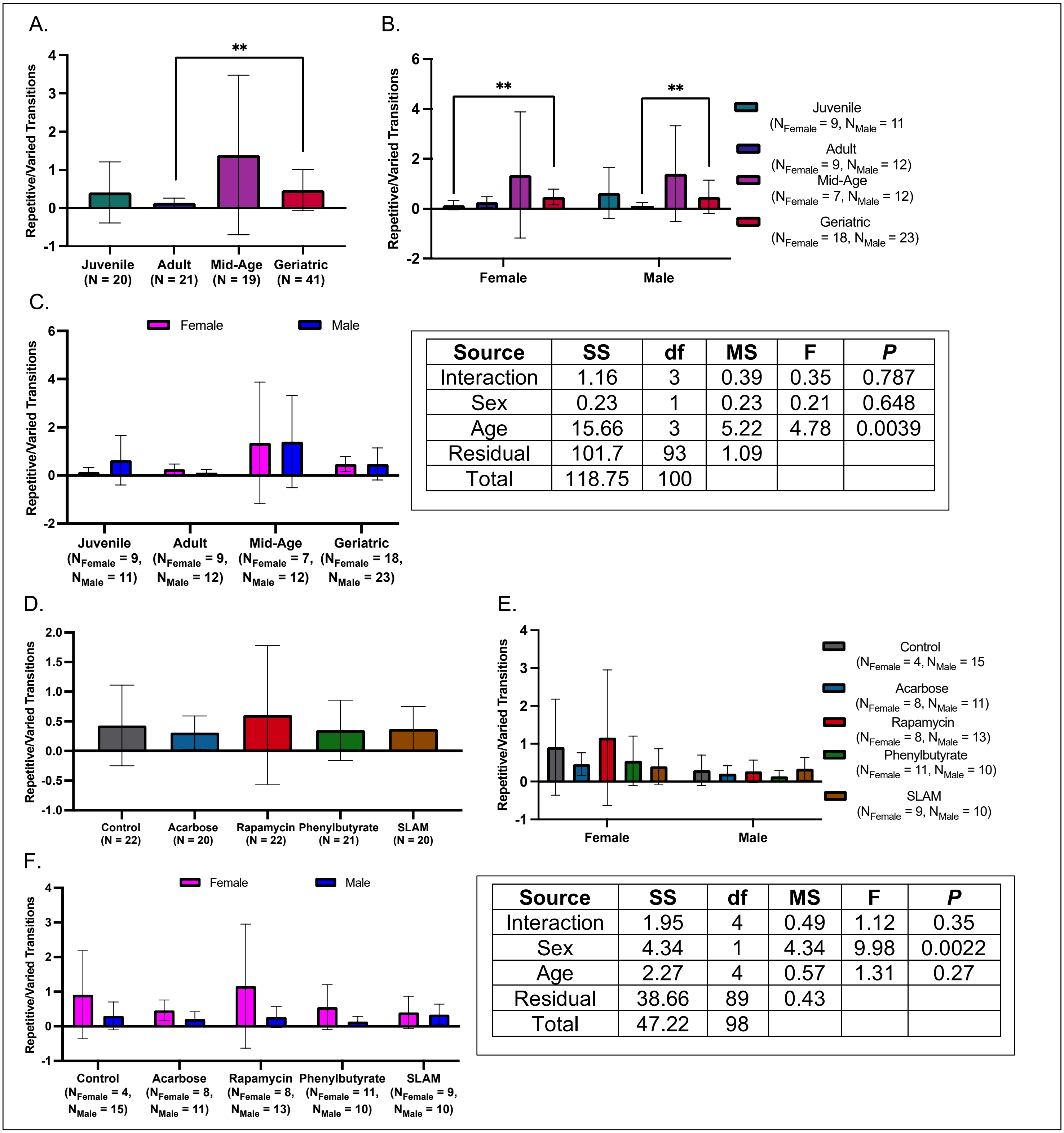


Figure 12. Age- and sex-related differences in proportion of repetitive tetragrams. (A-B) Proportion of repetitive tetragrams comparing juvenile to geriatric groups overall and sex stratified. **(C-D)** Proportion of repetitive tetragrams comparing adult to geriatric groups overall and sex stratified. **(E-F)** Proportion of repetitive tetragrams comparing mid-age to geriatric groups overall and sex stratified. **(G-H)** Proportion of repetitive tetragrams comparing treatment to control groups overall and sex stratified (*$P < 0.05$).

Transition ratios reflect subtle age effects but no treatment impact. Age-related differences were evident in the ratio of repetitive to varied tetragram transitions (Figure 13A). Mid-aged crickets (1.39 ± 2.09) trended higher ratios than geriatrics (0.47 ± 0.54; d = 0.72 [95% CI: 0.16, 1.28], P = 0.076), while adults (0.14 ± 0.12) had lower ratios (d = –0.67 [95% CI: –1.35, 0.01], P = 0.001). Juveniles (0.41 ± 0.80) did not differ from geriatrics (d = –0.10 [95% CI: –0.63, 0.44], P = 0.76). In males, mid-aged crickets (1.41 ± 1.92) trended higher than geriatric males (0.48 ± 0.67; d = 0.74 [95% CI: 0.02, 1.46], P = 0.13), adult males displayed reduced ratios (0.06 ± 0.06; d = –0.65 [95% CI: –1.63, 0.33], P = 0.008), and juvenile males were similar (0.63 ± 1.03; d = 0.19 [95% CI: –0.53, 0.91], P = 0.65) (Figure 13B). Among females, juveniles (0.14 ± 0.18) had lower ratios than geriatric females (0.47 ± 0.31; d = –1.14 [95% CI: –2.00, –0.29], P = 0.002), while adult (0.28 ± 0.27) and mid-aged groups (1.35 ± 2.53) were indistinct (d's = -1.02 to 0.03, P's = 0.070 to 0.96). No age-matched sex differences were detected (d's = –1.02 to 0.60, P's = 0.07 to 0.96) (Figure 13C).

Drug treatments did not influence repetitive-to-varied transition ratios (control: 0.43 ± 0.68; treatments: 0.31 to 0.61; d's = -0.21 to 0.18, P's = 0.39 to 0.90; Figure 13D). Neither female nor male subgroups exhibited treatment-related differences (d's = -0.61 to 0.14, P's = 0.64 to 0.93 for females, d's = -0.97 to -0.15, P's = 0.18 to 0.94 for males) (Figure 13E). No sex differences emerged within any treatment group (Figure 13F).



Source	SS	df	MS	F	*P*
Interaction	1.16	3	0.39	0.35	0.787
Sex	0.23	1	0.23	0.21	0.648
Age	15.66	3	5.22	4.78	0.0039
Residual	101.7	93	1.09		
Total	118.75	100			

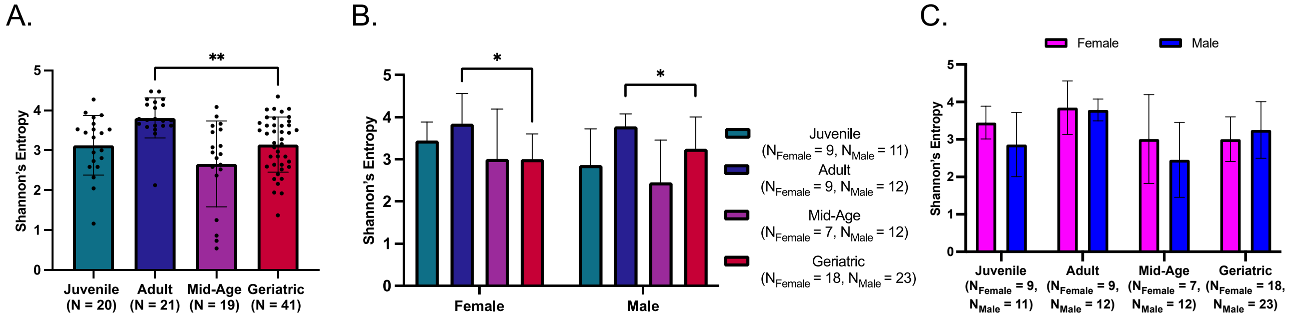
Source	SS	df	MS	F	*P*
Interaction	1.95	4	0.49	1.12	0.35
Sex	4.34	1	4.34	9.98	0.0022
Age	2.27	4	0.57	1.31	0.27
Residual	38.66	89	0.43		
Total	47.22	98			

Figure 13. Age- and sex-related differences in proportion of repetitive to varied transitions. (A) Adult crickets had lower proportions than their geriatric counterparts. **(B)** Sex-specific comparisons revealed juvenile males had less transitions than geriatric males while adult females had less than geriatric females. **(C)** No sex-dependent differences were observed

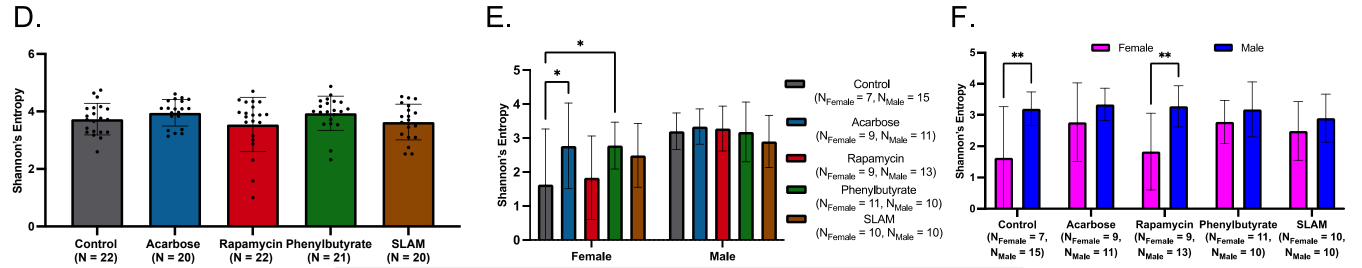
within age cohorts. **(D-E)** Treatment groups did not differ from controls in overall and sex-stratified analyses. **(F)** No within-group sex differences were observed in treatment cohorts (**P* < 0.05, ***P* < 0.01).

Entropy differentiates age-related strategy complexity but remains stable across treatments. To further assess age-related shifts in exploratory strategy within the Y-maze, entropy was calculated as a measure of movement pattern variability. Adult crickets (3.81 ± 0.50) exhibited greater entropy than geriatric individuals (3.14 ± 0.69; *d* = 1.04 [95% CI: 0.48, 1.60], *P* < 0.0001)*,* indicating more unpredictable behavioral sequences (Figure 14A). Mid-aged crickets (2.66 ± 1.07*)* trended lower (*d* = –0.57 [95% CI: –1.13, –0.02], *P* = 0.26), while juveniles (3.13 ± 0.75) resembled geriatrics (*d* = –0.02 [95% CI: –0.56, 0.51], *P* = 0.94). Sex-stratified analyses revealed nuanced differences (Figure 14B). Among females, adult crickets (3.83 ± 0.70) had higher entropy than geriatric females (2.98 ± 0.55; *d* = 1.40 [95% CI: 0.49, 2.31], *P* = 0.006). Juveniles showed a similar trend (3.44 ± 0.47; *d* = 0.88 [95% CI: 0.03, 1.72], *P* = 0.123), while mid-aged females (2.90 ± 1.17) were similar to geriatrics (*d* = –0.09 [95% CI: –1.09, 0.91], *P* > 0.99). In males, entropy was higher in adults (3.80 ± 0.29) compared to geriatric *(*3.25 ± 0.75; *d* = 0.82 [95% CI: 0.09, 1.54], *P* = 0.015)*,* while mid-aged males trended lower *(*2.45 ± 1.00; *d* = -0.92 [95% CI: -1.65, -0.19], *P* = 0.081*)*, and juveniles did not differ *(*3.13 ± 0.76; *d* = -0.16 [95% CI: -0.89, 0.58], *P* > 0.99*)*. No sex differences in entropy were detected within any age cohort (*d*'s = -0.47 to 0.41, *P* = 0.14 to 0.88) (Figure 14C).

Treatment did not affect entropy values (control: 2.70 ± 1.24; treatments: 2.69 to 3.08; *d*'s = -0.01 to 0.34, *P*'s = 0.35 to 0.83; Figure 14D). When stratified by sex, acarbose- (2.77 ± 1.26) and phenylbutyrate-treated females (2.78 ± 0.69) both had higher entropy than control females (1.63 ± 1.64; *d*'s = 0.75 to 0.95, *P* = 0.033 to 0.046), while male subgroups were unaffected across treatments (*d*'s = -0.46 to 0.24, *P*'s = 0.37 to 0.66; Figure 14E). However, a pronounced within-treatment sex difference emerged in the rapamycin group, where males (3.28 ± 0.66) displayed higher entropy than females (1.83 ± 1.23; *d* = 1.51 [95% CI: 0.54, 2.47], *P* = 0.0019) as well as the control group, where males (3.20 ± 0.54) also had higher entropy than females (1.63 ± 1.64; *d* = 1.50 [95% CI: 0.49, 2.51], *P* = 0.0013). No other group showed meaningful sex-specific divergence (*d*'s = 0.46 to 0.59, *P*'s = 0.32 to 0.45; Figure 14F).



Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	3.25	3	1.08	1.94	0.13
Sex	1.26	1	1.26	2.26	0.14
Age	11.90	3	3.97	7.12	0.0002
Residual	51.87	93	0.56		
Total	68.28	100			



Source	SS	df	MS	F	*P*
Interaction	6.79	4	1.70	2.07	0.091
Sex	19.55	1	19.55	23.81	<0.0001
Age	5.96	4	1.49	1.81	0.13
Residual	77.97	95	0.82		
Total	110.27	104			

Figure 14. Age- and sex-related differences in entropy. (A) Adult crickets displayed greater entropy than geriatric crickets. **(B)** Sex-specific entropy analysis revealed distinct trends, with females following the general age-related pattern, while males exhibited more variable age-dependent changes. **(C)** No sex differences in entropy were observed within individual age groups. **(D)** No difference between treatment groups. **(E)** When stratified by sex, acarbose and phenylbutyrate-treated females had higher entropy than controls. **(F)** Rapamycin-treated and control males had higher entropy values than their female counterparts (*$P < 0.05$, **$P < 0.01$).

Complete data tables can be found in Appendix 4. Table S1 and S2 are the proportion of repetitive tetragrams for the overall, male specific, and female specific data and the within group sex differences, respectively for the age group differences. Table S3 and S4 are the proportion of repetitive tetragrams for the overall, male specific, and female specific data and the within group sex differences, respectively for the treatment differences. Table S5 and S6 are the proportion of repetitive to varied transitions for the overall, male specific, and female specific data and the within group sex differences, respectively for the age group differences. Table S7 and S8 are the proportion of repetitive to varied transitions for the overall, male specific, and female specific data and the within group sex differences, respectively for the treatment group differences. Table S9 and S10 are the entropy values for the overall, male specific, and female specific data and the within group sex differences, respectively for the age group differences. Table S11 and S12 are the entropy values for the overall, male specific, and female specific data and the within group sex differences, respectively for the treatment group differences.

Extended exploration reveals time- and sex-dependent modulation of behavioral flexibility but not pharmacological rescue. To evaluate whether longer exploration durations might uncover treatment-dependent changes in behavioral strategy that are not detectable under brief conditions, we extended FMP Y-maze sessions to 40 minutes and performed tetragram analysis across the full set of 16 possible four-turn left–right sequences (Cleal et al., 2020). This approach enabled detailed assessment of exploratory structure over time and allowed us to disentangle the effects of treatment, sex, and session duration on both local and global aspects of behavioral variability.

Repetitive tetragram transitions, defined as sequential repetitions of the same four-turn pattern (e.g., LLLL→LLLL), were used as a proxy for lag-1 autocorrelation. These transitions were modeled as a binomial outcome using a generalized linear model (GLM) with fixed effects for *group*, *time*, *sex*, and their interaction:

$$logit(p_{ijk}) = \beta_0 + \beta_1 \cdot Group_i + \beta_2 \cdot Time_j + \beta_3 \cdot Sex_k + \beta_4 \cdot (Group_i\ x\ Time_j)$$

Where:

- p_{ijk} is the probability of a repetitive transition for individual *k* in group *I at time j.*
- $logit(p) = \log\left(\frac{p}{1-p}\right)$
- β_0 is the intercept (control, 10 min, female)
- Fixed effects include *Group*, *Time*, *Sex*, and their interaction (*Group x Time*)

The model revealed a low baseline probability of repetitive transitions in control animals during the first 10 minutes (β = –2.98, *SE* = 0.44, *P* < 0.001), indicating minimal stereotypy early in the session. None of the treatment groups differed from controls at this initial time point (*P*'s > 0.05), suggesting that acute behavioral rigidity was not modulated by drug exposure. However, a significant main effect of time was observed: repetitive transition frequency declined progressively across the session (Time 30 min: β = –0.42, *P* = 0.009; Time 40 min: β = –0.45, *P* = 0.004), indicating a shift toward more flexible, less patterned exploration as animals became more familiar with the environment. A strong sex effect was also detected, with males exhibiting fewer repetitive transitions than females across the session (β = –1.04, *SE* = 0.085, *P* < 0.001). No Group × Time interactions reached statistical significance, suggesting that the trajectory of reduced repetitiveness over time was consistent across treatment conditions.

To examine broader strategy diversity, we also calculated Shannon entropy for each animal's tetragram distribution per time bin. Entropy values were modeled using a linear model with the same fixed effects as follows:

$$Entropy_{ijk} = \beta_0 + \beta_1 \cdot Group_i + \beta_2 \cdot Time_j + \beta_3 \cdot Sex_k + \beta_4 \cdot (Group_i\ x\ Time_j) + \varepsilon_{ijk}$$

Where:

- $Entropy_{ijk}$ is the Shannon entropy of the tetragram distribution for subject *k* in group *i* at time *j*.
- ε_{ijk} is the residual error term, assumed to be normally distributed
- Fixed effects are the same as above

The results showed that entropy in control animals at 10 minutes was moderate (β = 2.79, *SE* = 0.10, *P* < 0.001), and no treatment group differed from controls across time bins (*P*'s > 0.05). However, male crickets exhibited consistently higher entropy than females (β = 0.43, *SE* = 0.07, *P* < 0.001), again supporting the interpretation that males engage in more variable exploratory strategies. Although entropy values increased slightly by 40 minutes, these time effects did not reach statistical significance (*P*'s > 0.05.

We also analyzed the percentage of tetragrams classified as alternations (LRLR, RLRL) and repetitions (LLLL, RRRR), treating these as continuous outcomes as follows:

$$Y_{ijk} = \beta_0 + \beta_1 \cdot Group_i + \beta_2 \cdot Time_j + \beta_3 \cdot Sex_k + \beta_4 \cdot (Group_i\ x\ Time_j) + \varepsilon_{ijk}$$

Where:

- Y_{ijk} is either:
  - $Alternation\ \% = \frac{LRLR+RLRL}{Total\ tetragrams}\ x\ 100$, or
  - $Reptition\ \% = \frac{LLLL+RRRR}{Total\ tetragrams}\ x\ 100$
- ε_{ijk} is the residual error term, assumed to be normally distributed

At baseline, alternation rates were modest in control animals (β = 6.37%, *SE* = 0.78, *P* < 0.001), and no treatment group differed from controls at this time point. Rapamycin-treated animals trended toward reduced alternation (β = –1.52%, *P* = 0.093), though this did not reach significance. Alternation frequency remained relatively stable across the session, and no time or Group × Time effects were detected. In contrast, repetition percentages declined over time, with the largest drop observed at 40 minutes (β = –3.11%, *SE* = 1.26, *P* = 0.014). As with entropy and autocorrelation, males showed lower repetition percentages than females (β = –3.97%, *SE* = 0.86, *P* < 0.001). No drug treatment significantly altered the trajectory of alternation or repetition behavior over time (*P*'s > 0.05).

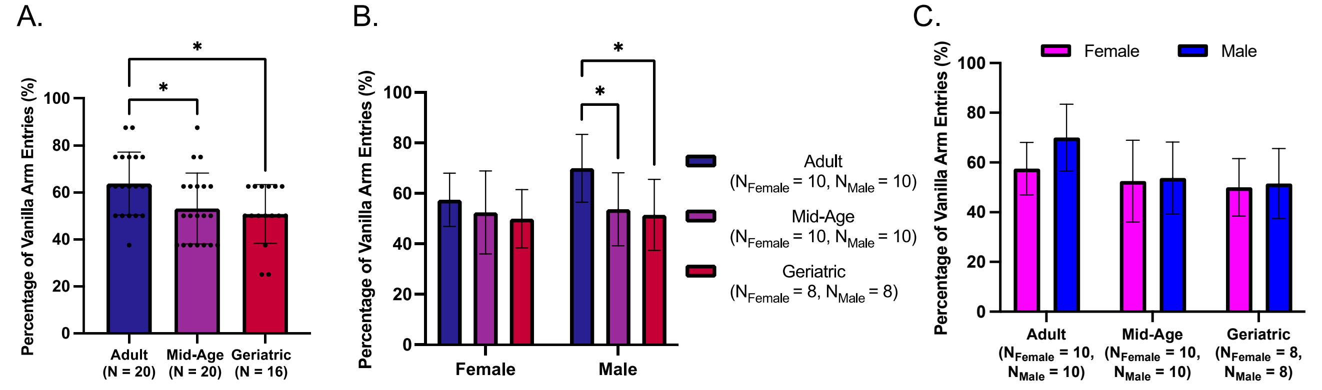
Olfactory distinction declines with age and is preserved by anti-aging interventions. Cognitive function was assessed through olfactory recognition using a Y-maze scent preference task. Adult crickets (63.75 ± 13.39%) exhibited a stronger preference for the vanilla-scented arm compared to both mid-aged (53.13 ± 15.11%) (*d* = 0.73 [95% CI: 0.09, 1.37], *P* = 0.047) and geriatric crickets (50.78 ± 12.47%) (*d* = 0.98 [95% CI: 0.28, 1.67], *P* = 0.019), while no differences were observed between mid-aged and geriatric cohorts (*d* = 0.16 [95% CI: -0.49, 0.82], *P* = 0.87) (Figure 15A). When stratified by sex, females showed no differences across age groups (Adult: 57.5 ± 10.54%; Mid-age: 52.5 ± 16.46%; Geriatric: 50.0 ± 11.57%) (*d* 's = 0.16 to 0.65, *P* 's = 0.48 to 0.92), whereas males recapitulated the overall trend, with adult males (70.0 ± 13.44%) demonstrating greater preference compared to mid-aged (53.75 ± 14.49%) (*d* = 1.11 [95% CI: 0.17, 2.06], *P* = 0.027) and geriatric males (51.56 ± 14.07%) (*d* = 1.28 [95% CI: 0.26, 2.30], *P* = 0.017) (Figure 15B). Sex-specific comparisons revealed that adult males trended toward higher preference compared to females (*d* = -0.99 [95% CI: -1.92, -0.06], *P* = 0.13), with no differences in other age groups (*d* 's = -0.11 to -0.08, *P* 's = 0.92 to 0.99) (Figure 15C).

In geriatric crickets treated with anti-aging interventions, acarbose (63.13 ± 14.89%), rapamycin (68.13 ± 13.13%), and phenylbutyrate (60.00 ± 11.89%) groups exhibited higher vanilla arm entries relative to controls (43.42 ± 13.42%) (*d* 's = -1.82 to -1.28, *P* 's = 0.0037 to < 0.0001), whereas combined treatment (56.25 ± 15.44%) showed a trending improvement (*d* = -0.87 [95% CI: -1.52, -0.21], *P* = 0.051) (Figure 15D). Stratified analyses revealed that rapamycin-treated females (68.06 ± 11.02%) showed higher preference compared to control females (47.50 ± 18.54%) (*d* = -1.38 [95% CI: -2.58, -0.17], *P* = 0.030), while acarbose (66.25 ± 14.49%), rapamycin (68.18 ± 15.17%), and phenylbutyrate-treated males (63.75 ± 12.43%) all surpassed controls (41.96 ± 11.61%) (*d* 's = -1.91 to -1.38, *P* 's = < 0.0001 to 0.030), with combined-treated males trending higher (55.68 ± 12.95%) (*d* = -1.09 [95% CI: -1.93, -0.24], *P* = 0.059) (Figure 15E). No sex differences were observed within treatment groups (*d* 's = -0.62 to 0.08, *P* 's > 0.99) (Figure 15F).

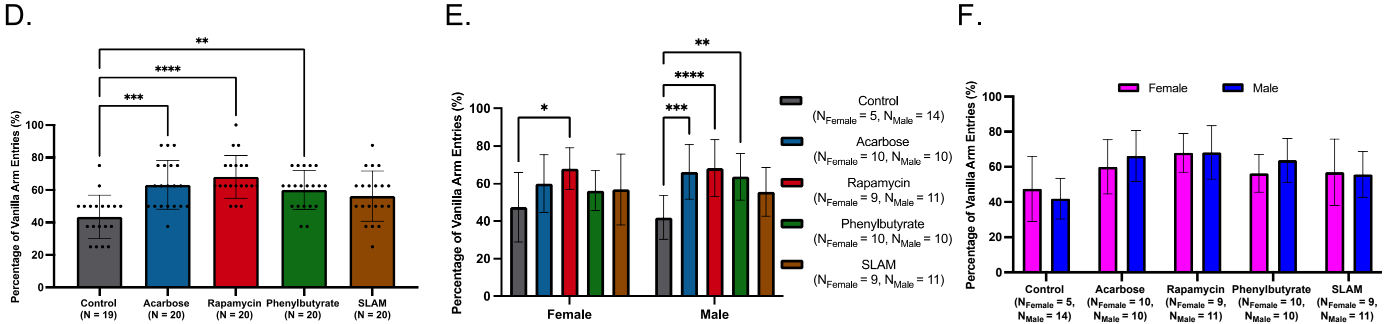
Relative to juveniles, only untreated controls exhibited reduced vanilla arm entries (*d* = 1.49 [95% CI: 0.78, 2.19], *P* = 0.0003), while treated groups were comparable to juvenile levels (*d* 's = -0.32 to 0.51, *P* 's = 0.64 to > 0.99) (Figure 15G). This age-related decline was specific to males, with no differences observed among females (*d* 's = -0.94 to 0.70, *P* 's = 0.33 to > 0.99) (Figure 15H). Compared to mid-aged crickets, rapamycin-treated crickets showed greater vanilla arm preference (*d* = -1.04 [95% CI: -1.70, -0.38], *P* = 0.010), while acarbose-treated crickets trended toward improvement (*d* = -0.65 [95% CI: -1.29, -0.02], *P* = 0.22) (Figure 15I). However, when stratified by sex, these differences were attenuated (*d* 's = -1.05 to 0.88, *P* 's = 0.079 to > 0.99), although trends persisted in rapamycin-treated males (*d* = -0.93 [95% CI: -1.83, -0.03], *P* = 0.086) and females (*d* = -1.05 [95% CI: -2.01, -0.09], *P* = 0.079) (Figure 15J). When compared to a historical geriatric cohort, rapamycin-treated crickets exhibited higher vanilla arm preference (*d* = -1.32 [95% CI: -2.05, -0.60], *P* = 0.0058), while acarbose- and phenylbutyrate-treated crickets trended higher (*d* 's = -0.87 to -0.74, *P* 's = 0.15 to 0.34) (Figure 15K). Sex-stratified analysis confirmed that rapamycin-treated females (*d* = -1.52 [95% CI: -2.60, -0.44], *P* = 0.035) and males (*d* = -1.08 [95% CI: -2.05, -0.10], *P* = 0.043) outperformed historical controls (Figure 15L).

Finally, relative to pooled historical controls, acarbose-, rapamycin-, and phenylbutyrate-treated crickets displayed higher vanilla arm preference (*d*'s = -1.61 to -1.03, *P* 's = 0.0070 to < 0.0001), while combined treatment again trended higher (*d* = -0.67 [95% CI: -1.23, -0.11], *P* =

0.13) (Figure 15M). Stratified analyses revealed that rapamycin-treated females (*d* = -1.45 [95% CI: -2.31, -0.58], *P* = 0.0077), and acarbose-, rapamycin-, and phenylbutyrate-treated males, all exhibited higher preference compared to controls (*d* 's = -1.49 to -1.24, *P*'s = 0.0030 to < 0.0001) (Figure 15N).

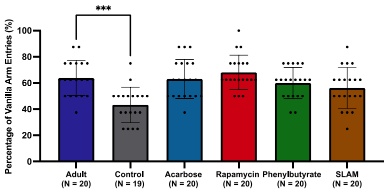


Source	SS	df	MS	F	*P*
Interaction	397.0	2	198.5	1.07	0.35
Sex	360.7	1	360.7	1.94	0.17
Group	1799	2	899.4	4.85	0.012
Residual	9277	50	185.5		
Total	11833	55			

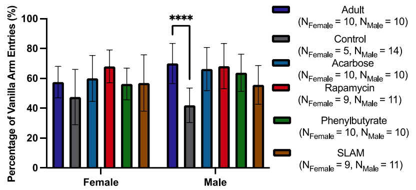


Source	SS	df	MS	F	*P*
Interaction	520.0	4	130.0	0.67	0.62
Sex	46.58	1	46.58	0.24	0.63
Group	5146	4	1286	6.60	0.0001
Residual	17346	89	194.9		
Total	23059	98			

G.

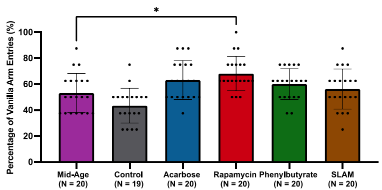


H.

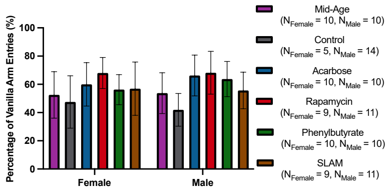


Source	SS	df	MS	F	*P*
Interaction	991.3	5	198.3	1.06	0.39
Sex	300.5	1	300.5	1.61	0.21
Group	5486	5	1097	5.88	<0.0001
Residual	19971	107	186.6		
Total	26749	118			

I.

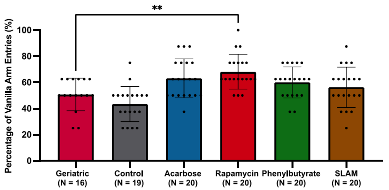


J.

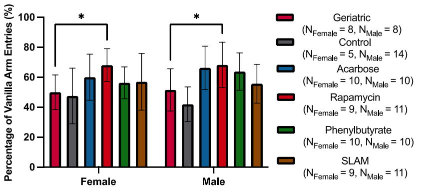


Source	SS	df	MS	F	*P*
Interaction	521.3	5	104.3	0.51	0.76
Sex	54.38	1	54.38	0.27	0.61
Group	5756	5	1151	5.68	0.0001
Residual	21674	107	202.6		
Total	28006	118			

K.

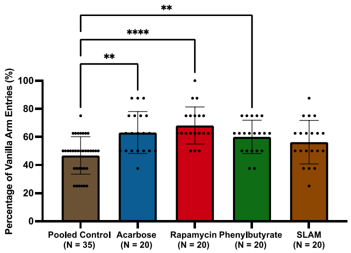


L.

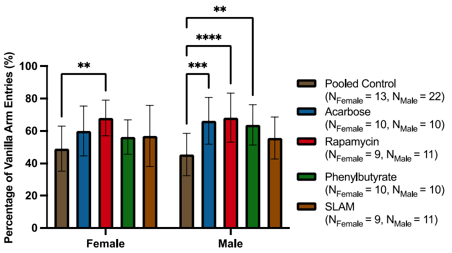


Source	SS	df	MS	F	*P*
Interaction	520.2	5	104.0	0.54	0.74
Sex	56.32	1	56.32	0.29	0.59
Group	6117	5	1223	6.41	<0.0001
Residual	19670	103	191.0		
Total	26364	114			

M.



N.



Source	SS	df	MS	F	*P*
Interaction	549.2	4	137.3	0.72	0.58
Sex	87.89	1	87.89	0.46	0.50
Group	6454	4	1613	8.40	<0.0001
Residual	20160	105	192.0		
Total	27251	114			

Figure 15. Anti-aging interventions preserve olfactory recognition memory in aged crickets. (A) Adult crickets exhibited greater vanilla arm preference compared to mid-aged and geriatric crickets. **(B)** Male crickets recapitulated overall trends, while females showed no age-associated changes. **(C)** Sex comparisons revealed a trend for greater vanilla preference in adult males versus females. **(D)** Acarbose, rapamycin, and phenylbutyrate treatments improved vanilla preference relative to controls in geriatric crickets. **(E)** Rapamycin-treated females and multiple treated males showed enhanced vanilla preference. **(F)** No sex differences were observed within treatment groups. **(G–H)** Only untreated controls, particularly males, exhibited reduced vanilla preference relative to juveniles. **(I–J)** Rapamycin-treated crickets outperformed mid-aged controls, with trends persisting in sex-stratified analyses. **(K–L)** Rapamycin improved vanilla preference relative to historical geriatric controls, in both sexes. **(M–N)** Acarbose, rapamycin, and phenylbutyrate treatments restored vanilla preference compared to pooled controls.

Comprehensive summary statistics are presented in Appendix 5. Group-level and sex-stratified age comparisons are detailed in Table S1, while sex-specific differences within age groups are reported in Table S2. Treatment group summaries are provided in Table S3 and S4, with sex-specific treatment comparisons outlined in Table S5. Comparisons between treatment groups and adults, mid-aged crickets, historical geriatrics, and pooled control geriatrics are summarized in Tables S6, S7, S8, and S9 respectively.

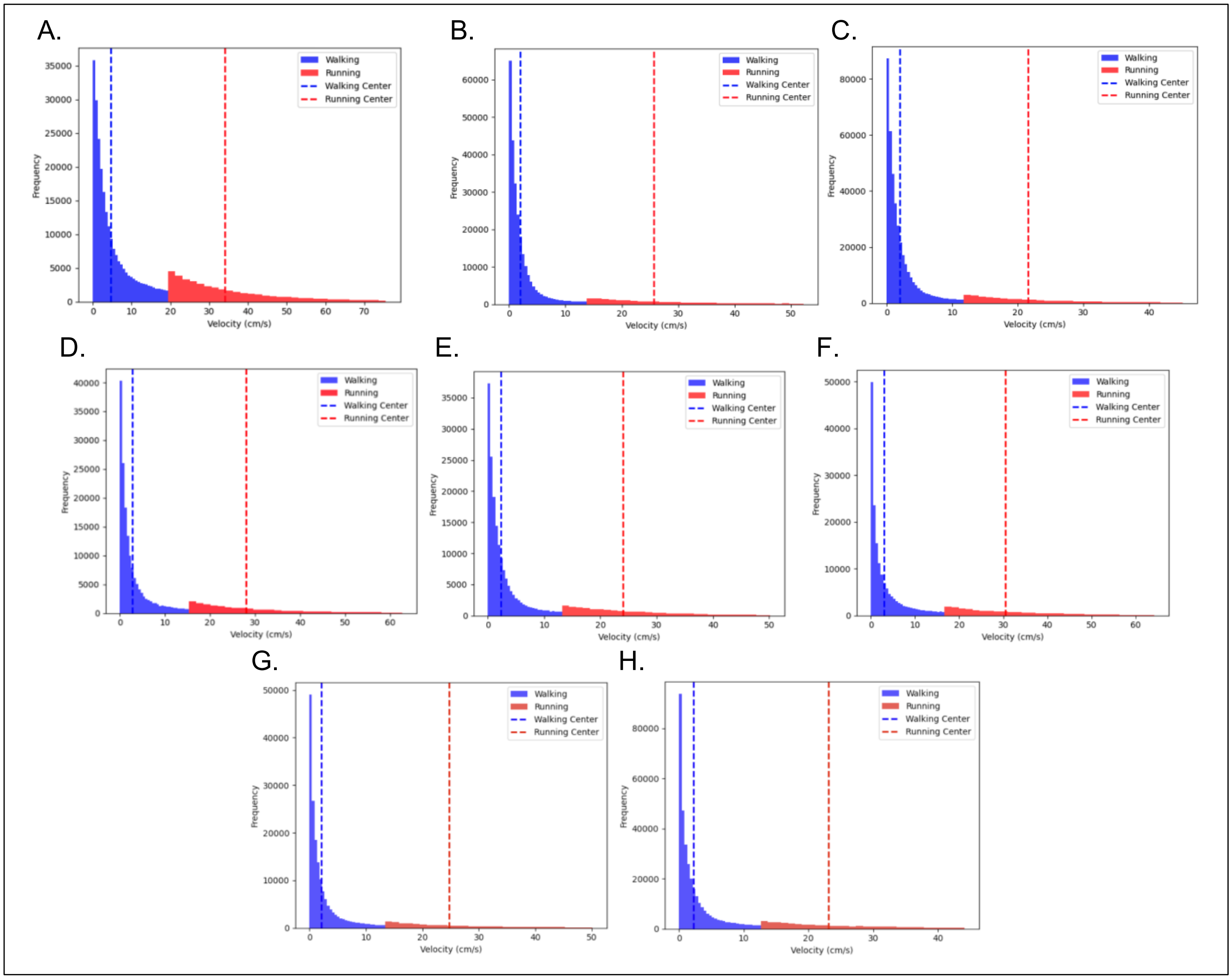
Velocity-defined clusters exhibit age- and treatment-dependent thresholds of walking and running in crickets.

To identify velocity cutoffs distinguishing walking from running across age and treatment groups, we applied unsupervised K-means clustering (k = 2) using only velocity data after removing values above the 99th percentile to exclude extreme outliers. Velocity was derived from ezTrack's "Location_output", which uses center-of-mass tracking to calculate frame-by-frame displacement (Pennington et al., 2021). Age specific 99th percentile velocity cutoffs declined with age, with juvenile crickets exhibiting the highest cutoff (75.51 cm/s), followed by adults (52.20 cm/s) and geriatrics (45.12 cm/s). Treatment-specific cutoffs varied, with rapamycin-treated crickets exhibiting the highest threshold (64.30 cm/s), followed by control (62.77 cm/s), SLAM (50.78 cm/s), acarbose (50.20 cm/s), and phenylbutyrate (50.16 cm/s).

Initial clustering consistently revealed two visually distinct distributions. To quantify cluster separability, we computed the mean and standard deviation of velocity within each cluster, identifying age- and treatment-dependent differences in walking and running speeds. Juvenile crickets exhibited higher walking (4.66 ± 4.69 cm/s) and running (34.02 ± 13.10 cm/s) thresholds relative to adults (walking: 2.03 ± 2.47 cm/s; running: 25.62 ± 9.80 cm/s) and geriatrics (walking: 1.97 ± 2.25 cm/s; running: 21.56 ± 8.31 cm/s), consistent with an age-related decline in movement speed (Figure 16A-C). Treatment effects were also apparent, as rapamycin-treated individuals demonstrated the highest walking (2.93 ± 3.69 cm/s) and running (30.51 ± 11.64 cm/s) thresholds, relative to control (walking: 2.73 ± 3.28cm/s; running: 28.05 ± 11.22 cm/s), acarbose (walking: 2.33 ± 2.67 cm/s; running: 24.07 ± 8.95 cm/s), SLAM (walking: 2.30 ± 2.88 cm/s; running 25.08 ± 9.20 cm/s), and phenylbutyrate (walking: 2.12 ± 2.68 cm/s; running 24.70 ± 9.48 cm/s) (Figure 16D-H).

To validate these clusters using an orthogonal measure of activity, we incorporated motion magnitude, a metric derived from frame-to-frame pixel changes in the "Freezing_output" pipeline in ezTrack. Unlike velocity, which is computed from positional displacement, motion magnitude captures full-frame changes in pixel intensity, offering an independent estimate of movement dynamics (Pennington et al., 2021). To circumvent computational limitations from our >200,000-point dataset ($O(n^2)$ pairwise distances for silhouette scoring, we simulated a representative dataset of 2,000 points by sampling from bivariate normal distributions defined by the empirical means and standard deviations of each cluster's velocity and motion magnitude. This approach retained key distributional properties while avoiding the statistical confounds associated with imbalanced cluster sizes and non-convex shapes (Handl et al., 2005).

Two-dimensional K-means clustering (k = 2) was applied to the simulated dataset, followed by silhouette analysis to evaluate intra-cluster cohesion and inter-cluster separation (Rousseeuw 1987). Silhouette scores across all groups exceeded the conventional threshold of 0.5, indicating well-separated clusters (Dalmaiher et al., 2022). Age-based average silhouette scores were juvenile (0.640), adult (0.648), geriatric (0.655), and treatment-based scores further confirmed the robustness of clustering (control: 0.600; acarbose: 0.647; rapamycin: 0.641; phenylbutyrate: 0.624; SLAM: 0.636). Corresponding silhouette plots and cluster visualizations are presented in Figure 16I-P.



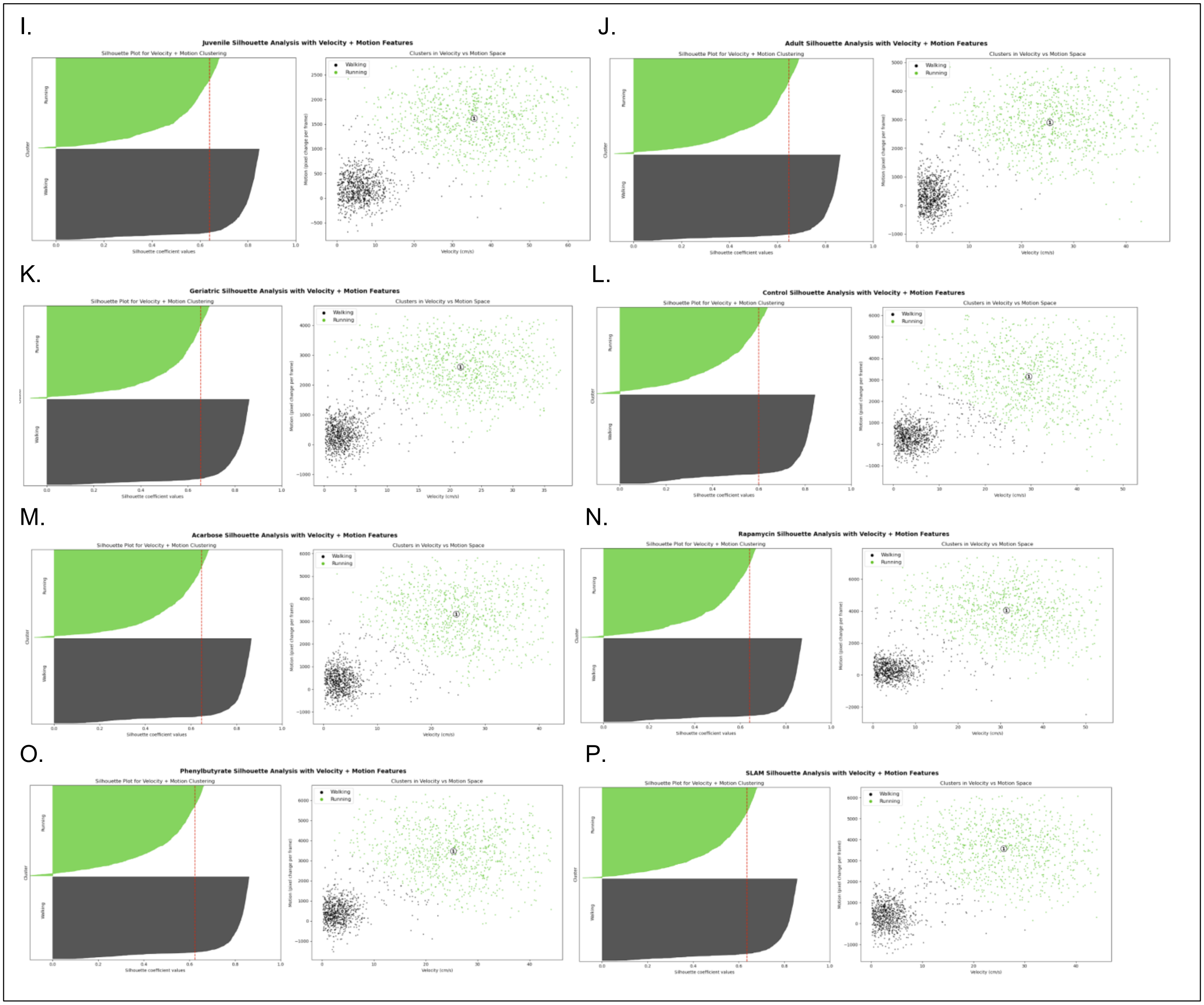


Figure 16. Age- and treatment-dependent velocity distributions and silhouette-based cluster validation. (A-C) Probability density plots of velocity (cm/s) in juvenile, adult, and geriatric crickets (left to right), show a progressive age-related decline in maximum locomotor speed. Vertical dashed lines represent clustering centroids used for analyses. **(D-H)** Velocity distributions for control, acarbose, rapamycin, phenylbutyrate, and SLAM (combined treatment) cohorts (left to right) cohorts reveal treatment-dependent differences in maximal speed profiles. **(I-K)** Two-dimensional K-means clustering using velocity and motion magnitude metrics for juvenile, adult, and geriatric cohorts (left to right). Left: Silhouette plots illustrating the compactness and separation of clusters; Right: Cluster visualizations showing distinct separation between walking and running datapoints. **(L-P)** Silhouette plots (left) and corresponding cluster visualizations (right) for control, acarbose, rapamycin (L-N: left to right), phenylbutyrate, and SLAM treatment groups (O-P: left to right). In all conditions, average silhouette scores (vertical red lines) exceeded 0.5, indicating well-defined cluster boundaries based on both center-of-mass velocity and independent motion magnitude metrics.

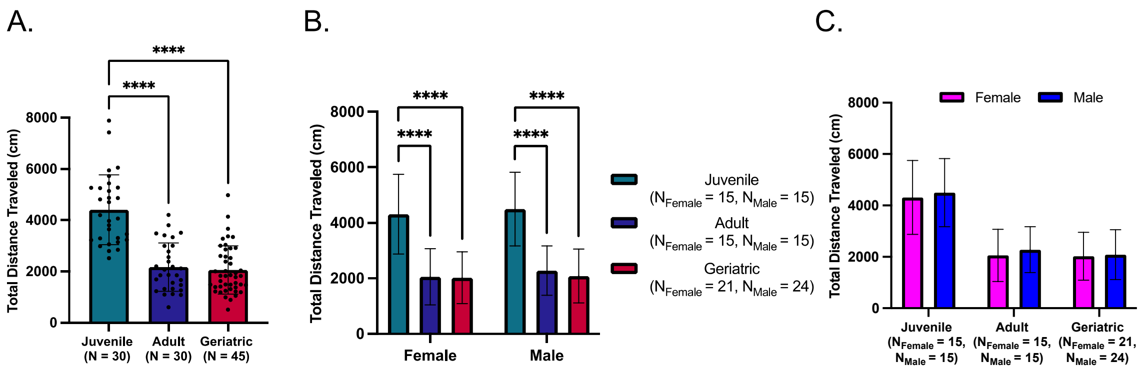
Rapamycin mitigates age-associated locomotor decline in geriatric crickets, with male-specific restoration of juvenile-like activity. Locomotor capacity declined with age, as juvenile crickets traversed markedly greater distances (4405 ± 1364 cm) than both adult (2167 ± 945 cm) and geriatric individuals (2057 ± 941 cm). These reductions were large in magnitude (*d* = 1.88 [95% CI: 1.27, 2.49], *P* < 0.0001 for both comparisons), yet no additional decline was detected between adult and geriatric stages (*d* = 0.12 [95% CI: -0.35, 0.58], *P* = 0.90), indicating that the most substantial deterioration in activity emerged early in the aging trajectory (Figure 17A). Stratification by sex revealed parallel declines in both females and males. Juvenile females traveled greater distances than adult and geriatric counterparts (4313 ± 1440 cm vs. 2054 ± 1014 cm and 2023 ± 931 cm, respectively; *d*'s = 1.76 to 1.92, *P*'s < 0.0001), with no further loss between adult and geriatric stages (*d* = 0.03 [95% CI: -0.63, 0.69], *P* > 0.99) (Figure 17B). Similarly, male juveniles (4496 ± 1328 cm) outpaced adult and geriatric males (2279 ± 891 cm and 2086 ± 969 cm, respectively; *d's* = 1.91-2.11, *P*'s < 0.0001), with stable levels thereafter (*d* = 0.20 [95% CI: -0.45, 0.85], *P* = 0.85). Across all age groups, sex-based differences in distance traveled were minimal (*d*'s = -0.23 to -0.07, *P*'s > 0.99) (Figure 17C).

Among geriatric treatment cohorts, total distance traveled did not differ substantially across controls (2938 ± 885 cm) and acarbose- (2542 ± 925 cm), rapamycin- (3340 ± 1283 cm), or SLAM-treated groups (2523 ± 1131 cm) (*d*'s = -0.36 to 0.43, *P*'s = 0.51 to 0.55), while phenylbutyrate-treated crickets had a modest trend toward reduced locomotion (2245 ± 705; *d* = 0.85 [95% CI: 0.20, 1.51], *P* = 0.11) (Figure 17D). Sex-stratified analyses revealed no detectable differences within females (*d*'s = -0.29 to 0.33, *P*'s = 0.90 to 0.96) or males (*d*'s = -0.42 to 0.52, *P*'s = 0.53 to 0.70), though phenylbutyrate-treated males trended toward reduced activity (*d* = 1.49 [95% CI: 0.50, 2.48], *P* = 0.08) (Figure 17E). No treatment group demonstrated sex-based differences in performance (*d*'s = -0.53 to 0.40, *P*'s = 0.63 to > 0.99) (Figure 17F).

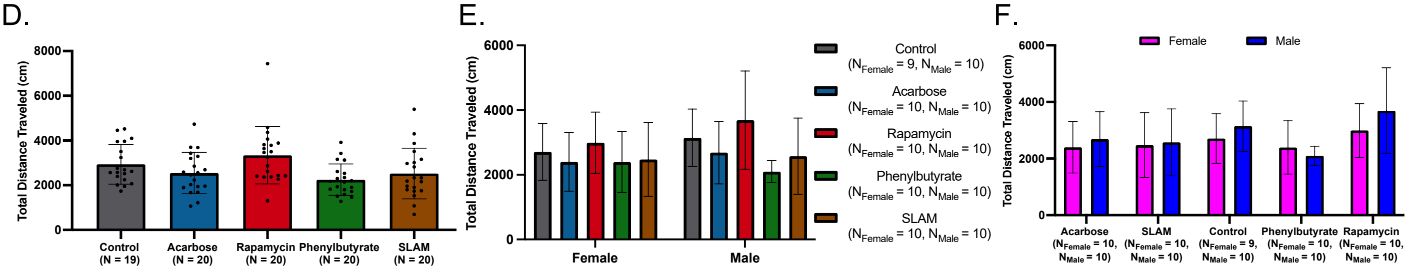
Relative to juveniles, all geriatric groups displayed reduced locomotion (*d*'s = 0.79 to 1.52, *P*'s = 0.0051 to <0.0001), with this decline remaining consistent across treatments in females (*d*'s = 1.01 to 1.47, *P*'s = 0.02 to 0.0002) (Figure 17G). Notably, rapamycin-treated males performed at levels statistically indistinguishable from juveniles (*d* = 0.56 [95% CI: -0.26, 1.37], *P* = 0.29), whereas all other male groups remained impaired (*d*'s = 1.11 to 2.19, *P*'s = 0.016 to <0.0001) (Figure 17H). Compared to adults, rapamycin-treated geriatric males exhibited enhanced locomotor capacity (*d* = -0.82 [95% CI: -1.42, -0.23], *P* = 0.041), a pattern also observed in untreated controls (*d* = -1.06 [95% CI: -1.66, -0.46], *P* = 0.0004) (Figure 17I). However, only the rapamycin-treated males exceeded adult-level performance following sex stratification (*d* = -1.16 [95% CI: -2.02, -0.30], *P* = 0.004) (Figure 17J).

When benchmarked against a historical geriatric cohort, both the current control (*d* = -0.94 [95% CI: -1.50, -0.38], *P* = 0.0067) and rapamycin-treated groups (*d* = -1.20 [95% CI: -1.77, -0.63], *P* < 0.0001) exhibited markedly elevated activity (Figure 17K). This improvement was driven by males, with both control (*d* = -1.09 [95% CI: -1.87, -0.31], *P* = 0.03) and rapamycin-treated (*d* = -1.36 [95% CI: -2.17, -0.56], *P* = 0.0002) crickets outperforming their historical counterparts. No treatment group among females showed such improvements (*d*'s = -1.01 to -0.39, *P*'s = 0.06 to 0.84) (Figure 17L).

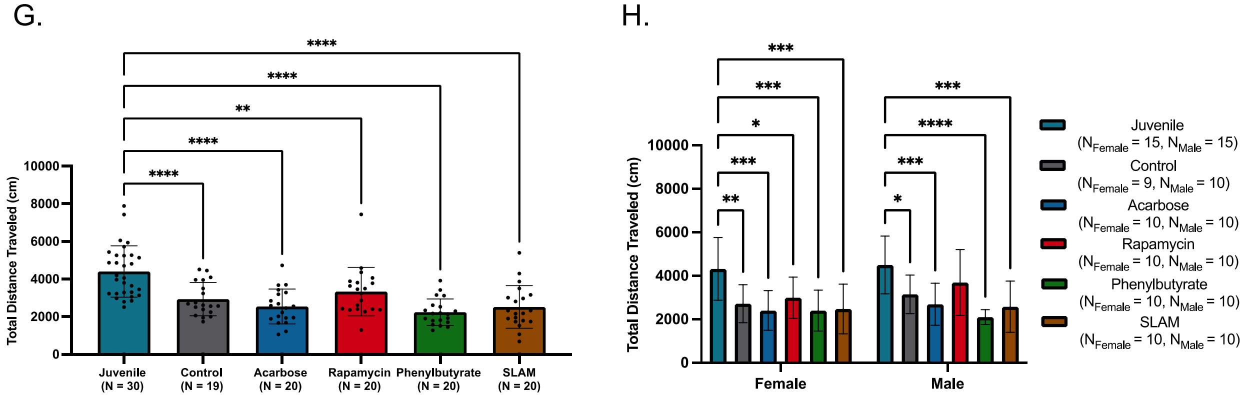
Finally, in the overall cohort, rapamycin-treated crickets exhibited greater locomotor activity, covering more total distance than pooled controls (*d* = –0.94, [95% CI: -1.46, -0.42], *P* = 0.0006), whereas the other treatment groups showed no appreciable differences (*d*'s = –0.23 to 0.08, *P*'s = 0.85 to > 0.99) (Figure 17M). Upon stratification by sex, rapamycin-treated females trended toward increased total distance compared to female controls (*d* = -0.85 [95% CI: -1.58, -0.12], *P* = 0.10), while the remaining female groups did not differ from controls (*d*'s = -0.31 to -0.25, *P*'s = 0.84 to 0.94). A similar pattern was observed among males, where rapamycin treatment was associated with higher total distance traveled (*d* = -1.09 [95% CI: -1.83, -0.35], *P* = 0.0026); other male treatment groups showed no consistent deviation from control performance (d's = -0.27 to 0.31, *P*'s = 0.87 to 0.98) (Figure 17N).



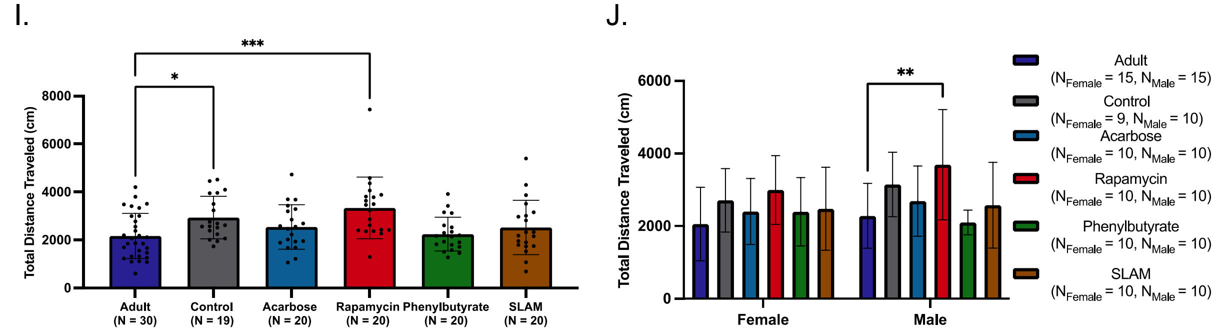
Source	SS	df	MS	F	*P*
Interaction	1.34e05	2	6.69e04	0.06	0.95
Sex	6.23e05	1	6.23e05	0.52	0.47
Group	1.14e08	2	5.70e07	47.77	<0.0001
Residual	1.18e08	99	1.19e06		
Total	2.32e08	105			



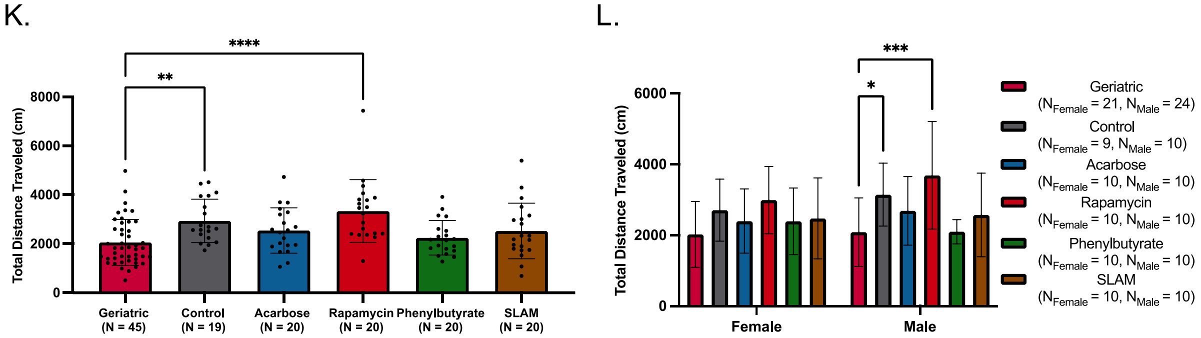
Source	SS	df	MS	F	*P*
Interaction	2.78e06	4	6.96e05	0.68	0.608
Sex	1.47e06	1	1.47e06	1.44	0.234
Group	1.43e07	4	3.60e06	3.51	0.010
Residual	9.12e07	89	1.02e06		
Total	1.10e08	98			



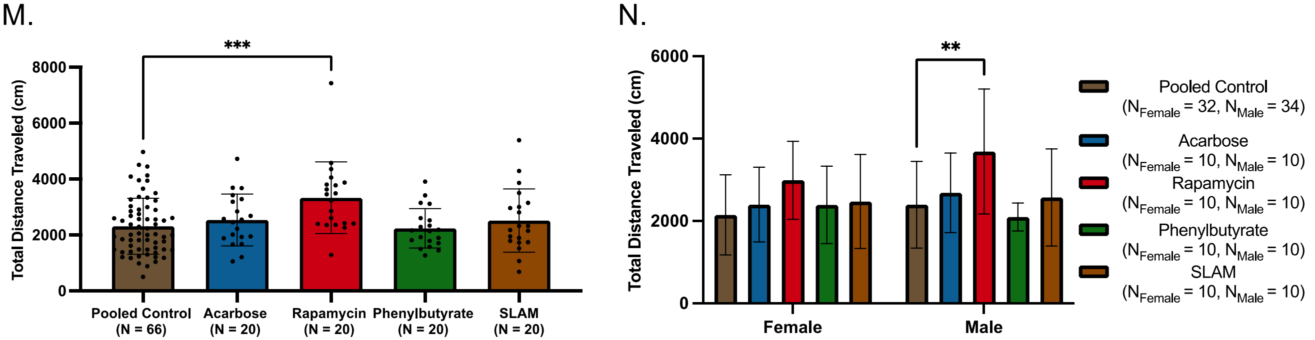
Source	SS	df	MS	F	*P*
Interaction	2.8e06	5	5.6e05	0.45	0.81
Sex	1.7e06	1	1.7e06	1.34	0.24
Group	8.0e07	5	1.6e07	12.97	<0.0001
Residual	1.4e08	117	1.2e06		
Total	2.25e08	128			



Source	SS	df	MS	F	*P*
Interaction	2.8e06	5	5.6e05	0.56	0.73
Sex	1.8e06	1	1.8e06	1.83	0.18
Group	2.2e07	5	4.3e06	4.27	0.0013
Residual	1.2e08	117	1.0e06		
Total	1.47e08	128			



Source	SS	df	MS	F	*P*
Interaction	3.0e06	5	6.1e05	0.62	0.69
Sex	1.5e06	1	1.5e06	1.52	0.22
Group	2.8e07	5	5.6e06	5.64	<0.0001
Residual	1.3e08	132	9.9e05		
Total	1.63e08	143			



Source	SS	df	MS	F	*P*
Interaction	2.6e06	4	6.5e05	0.61	0.65
Sex	1.2e06	1	1.2e06	1.17	0.28
Group	1.9e07	4	4.7e06	4.44	0.0021
Residual	1.4e08	136	1.1e06		
Total	1.63e08	145			

Figure 17. Age- and treatment-effects on total distance traveled. (A) Juveniles traveled farther than adults or geriatrics. **(B)** Age-related declines were observed in both sexes, with no

further reduction beyond adulthood. **(C)** No sex-based differences were detected within any age group**.** **(D)** Total distance traveled was similar across all geriatric treatment groups. **(E)** Within-sex comparisons revealed no treatment-related differences. **(F)** No within-treatment sex differences in geriatric groups. **(G)** All geriatric cohorts showed reduced locomotion relative to juveniles. **(H)** Rapamycin-treated males exhibited juvenile-like locomotion. **(I)** Rapamycin and controls outperformed adults. **(J)** Only rapamycin-treated males surpassed adult-level performance following sex stratification. **(K)** Current control and rapamycin-treated groups outperformed historical geriatric cohorts. **(L)** Male-specific locomotor enhancement drove this improvement. **(M)** Rapamycin-treated crickets traveled further than pooled controls. **(N)** Male-specific locomotor enhancement drove this improvement (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ****$P < 0.0001$).

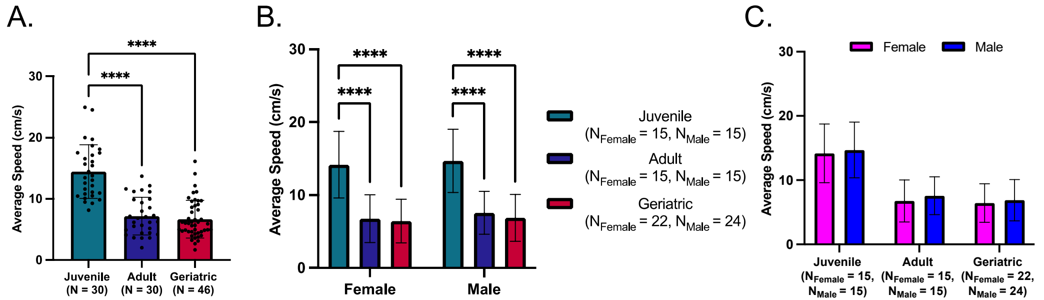
Rapamycin reverses age-associated reduction in locomotor speed, particularly in males. Crickets exhibited robust age-related declines in average locomotor speed. Juveniles moved faster than both adult and geriatrics (14.44 ± 4.38 cm/s vs. 7.17 ± 3.08 cm/s and 6.67 ± 3.08 cm/s, respectively; *d*'s = 1.90-2.11, *P*'s < 0.0001). Speeds between adults and geriatrics were comparable (*d* = 0.16 [95% CI: –0.30, 0.62], *P* = 0.82) (Figure 18A). When stratified by sex, juvenile females moved faster than adult (6.76 ± 3.27 cm/s) and geriatric females (6.43 ± 2.99 cm/s) (*d*'s = 1.81-2.03, *P*'s < 0.0001), with no differences between adult and geriatrics (*d* = 0.10 [95% CI: -0.56, 0.77], *P* = 0.96). Similarly, juvenile males exceeded adult (7.57 ± 2.93 cm/s) and geriatric males (6.88 ± 3.21 cm/s) in speed (*d* = 1.87-2.08, *P*'s < 0.0001), with no differences between adults and geriatrics (*d* = 0.22 [95% CI: -0.43, 0.86], *P* = 0.82) (Figure 18B). No sex effects were observed in average speed within any age group (*d*'s = -0.25 to -0.11, *P*'s > 0.99) (Figure 18C).

Within the geriatric groups, average speed did not differ across control (9.34 ± 2.83 cm/s), acarbose- (8.38 ± 3.05 cm/s), rapamycin- (11.02 ± 4.19 cm/s), or SLAM-treated (8.25 ± 3.77 cm/s) crickets (*d*'s = -0.46 to 0.32, *P*'s = 0.31 to 0.77), although phenylbutyrate (7.39 ± 2.25 cm/s) trended lower (*d* = 0.75, [95% CI: 0.10, 1.40], *P* = 0.20) (Figure 18D). This pattern persisted when stratified by sex (*d*'s = -0.50 to 0.41, *P*'s = 0.40 to 0.98), although phenylbutyrate-treated males trended lower (*d* = 1.32 [95% CI: 0.35, 2.28], *P* = 0.14) (Figure 18E). No within-group sex differences were detected across any treatment (*d*'s = -0.51 to 0.38, *P*'s = 0.68 to > 0.99) (Figure 18F).

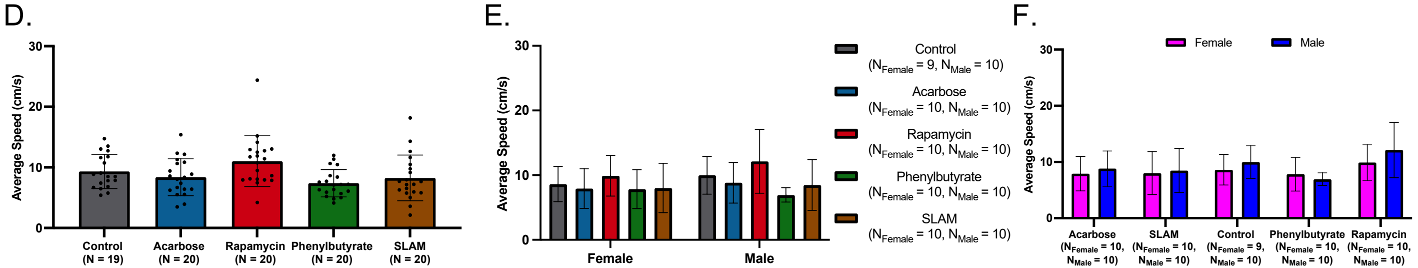
Compared to juveniles, all geriatric treatment groups moved at slower speeds (*d*'s = 0.78 to 1.88, *P*'s = 0.0060 to <0.0001) (Figure 18G). This age-related decline was preserved in both sexes (*d*'s = 1.01 to 2.17, *P*'s = 0.020 to < 0.0001), except for rapamycin-treated males, who matched juvenile speeds (*d* = 0.55 [95% CI: -0.27, 1.36], *P* = 0.31) (Figure 18H). When compared to adults, all treatment groups showed similar speeds (*d*'s = -1.06 to -0.08, *P*'s = 0.10 to > 0.99), except for the rapamycin-treated group, which moved faster than adults (*d* = -1.06 [95% CI: -1.67, 0.46], *P* = 0.0003) (Figure 18I). When stratified by sex, this increase in speed was observed only in rapamycin-treated males (*d* = -1.14 [95% CI: -2.00, -0.28], *P* = 0.004) without differences in any of the other treatment groups (*d*'s = -0.80 to 0.25, *P*'s = 0.27 to > 0.99), while all other groups, including rapamycin-treated females, remained comparable to adults (*d*'s = -0.94 to -0.33, *P*'s = 0.08 to 0.91) (Figure 18J).

Relative to a historical geriatric cohort, both the current control and rapamycin-treated groups displayed higher average speeds (*d* = -0.88 [95% CI: -1.43, -0.32], *P* = 0.014 and *d* = -1.24 [95% CI: -1.81, -0.68], *P* < 0.0001, respectively) (Figure 18K). When analyzed by sex, rapamycin-treated males and females outpaced the historical cohort (*d*'s = -1.35 to -1.11, *P*'s = 0.03 to 0.0002), while control males trended faster (*d* = -0.97 [95% CI: -1.74, -0.19], *P* = 0.06). All other treatment groups matched historical cohort speeds (*d*'s = -0.73 to -0.46, *P*'s = 0.35 to > 0.99) (Figure 18L).

Across the overall cohort, rapamycin-treated crickets demonstrated faster average speeds relative to pooled controls (*d* = –1.02 [95% CI: -1.54, -0.49], *P* = 0.0002), while no meaningful differences were observed among the remaining treatment groups (*d*'s = -0.29 to 0.02, *P*'s = 0.70 to > 0.99) (Figure 18M). In sex-stratified analyses, females treated with rapamycin trended toward faster average speeds compared to female controls (*d* = -0.84 [95% CI: -1.59, -0.09], *P* = 0.11), whereas no other female treatment group differed (*d*'s = -0.24 to -0.20, *P*'s = 0.93 to 0.97). Among males, rapamycin-treated individuals similarly exhibited higher average speeds (*d* = –1.13 [95% CI: -1.87, -0.39], *P* = 0.0019), while the remaining male groups showed comparable speeds to controls (*d*'s = -0.31 to 0.27, *P*'s = 0.85 to 0.96) (Figure 18N).



Source	SS	df	MS	F	*P*
Interaction	0.63	2	0.31	0.03	0.98
Sex	8.90	1	8.90	0.71	0.40
Group	1240	2	619.80	49.57	<0.0001
Residual	1250	100	12.50		
Total	2499	105			



Source	SS	df	MS	F	*P*
Interaction	26.64	4	6.67	0.61	0.659
Sex	16.43	1	16.43	1.50	0.225
Group	152.4	4	38.11	3.47	0.011
Residual	977.4	89	10.98		
Total	1172.9	98			

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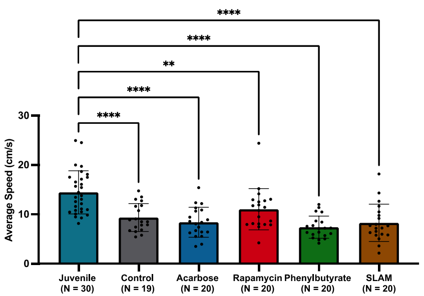

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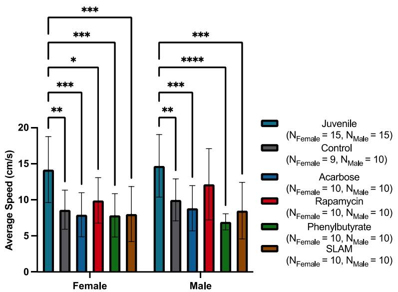

Source	SS	df	MS	F	*P*
Interaction	27.10	5	5.421	0.41	0.84
Sex	18.49	1	18.49	1.41	0.24
Group	866.8	5	173.4	13.23	<0.0001
Residual	1533	117	13.10		
Total	2445.4	128			

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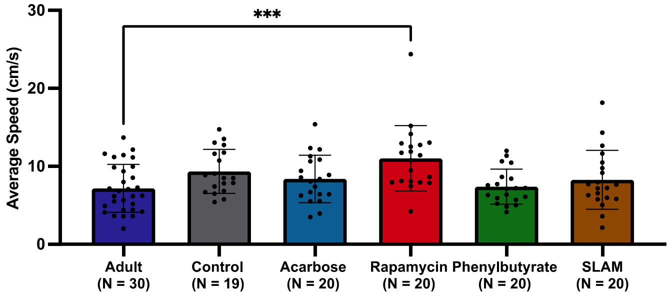

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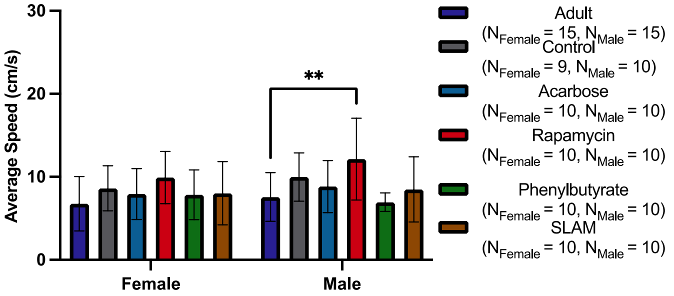
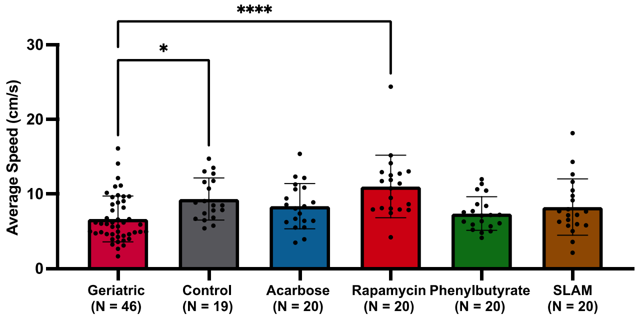


Source	SS	df	MS	F	*P*
Interaction	26.64	5	5.328	0.50	0.78
Sex	20.84	1	20.84	1.96	0.16
Group	218.9	5	43.78	4.11	0.0018
Residual	1247	117	10.66		
Total	1513.4	128			

K.



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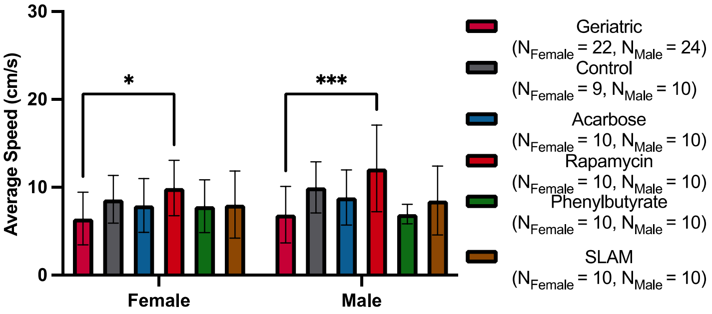
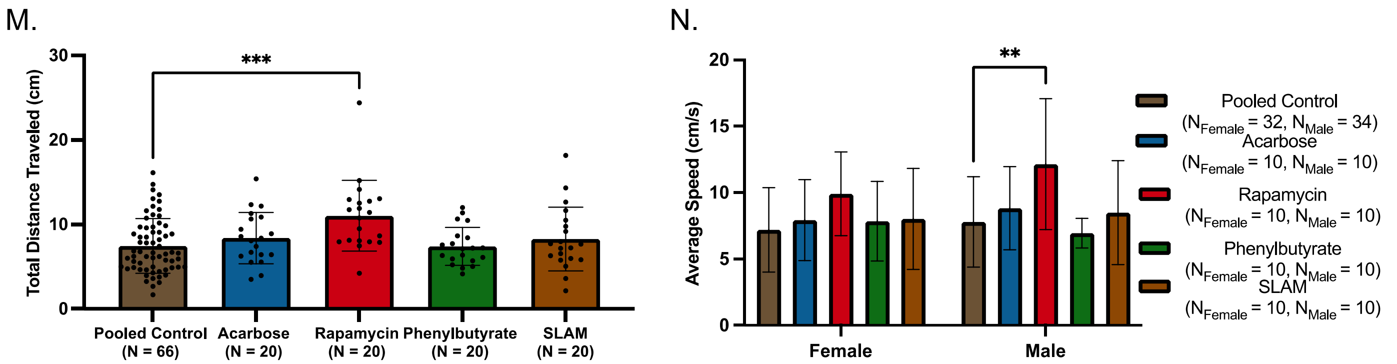


Source	SS	df	MS	F	*P*
Interaction	27.70	5	5.54	0.53	0.76
Sex	18.58	1	18.58	1.76	0.19
Group	305.5	5	61.09	5.79	<0.0001
Residual	1403	132	10.55		
Total	1754.8	143			



Source	SS	df	MS	F	*P*
Interaction	24.86	4	6.22	0.55	0.70
Sex	12.65	1	12.65	1.12	0.29
Group	204.2	4	51.05	4.50	0.0019
Residual	1497	132	11.34		
Total	1739	141			

Figure 18. Age- and treatment-effects on average speed. (A) Juveniles moved faster than adults and geriatrics. **(B)** Juvenile males and females outpaced older cohorts. **(C)** No sex differences in speed within age groups. **(D)** No treatment effects in overall geriatric cohort. **(E)** No treatment effects when stratified by sex. **(F)** No sex differences within any treatment group. **(G)** All treatments moved slower than juveniles. **(H)** Only rapamycin-treated males matched juvenile speeds. **(I)** Rapamycin-treated group exceeded adult speeds. **(J)** Rapamycin-treated males, but not females, moved faster than adults. **(K)** Current control and rapamycin-treated outpaced historical geriatrics. **(L)** Rapamycin-treated males and females outperformed historical cohort. **(M)** Rapamycin-treated crickets traveled faster than pooled controls. **(N)** Male-specific locomotor enhancement drove this improvement (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ****$P < 0.0001$).

Geriatric and acarbose-treated crickets shift toward lower-intensity locomotion that is rescued by rapamycin in males. Geriatric crickets displayed the highest walking-to-running distance ratios (3.40 ± 1.51), followed by adults (2.72 ± 1.16), with juveniles exhibiting the lowest ratios (1.93 ± 0.31), consistent with an age-related decline in high-intensity locomotion (d’s = -1.22 to –0.49 P’s = 0.04, P’s < 0.0001) (Figure 19A). When stratified by sex, juvenile females exhibited lower ratios (1.94 ± 0.35) compared to geriatrics (3.14 ± 1.40) (d = -1.07 [95% CI: -1.78, -0.36], P = 0.009) and trended lower than adults (2.48 ± 0.82) (d = -0.83 [95% CI: -1.58, -0.09], P = 0.42). Adult and geriatric females did not differ (d = -0.54 [95% CI: -1.21, 0.13], P = 0.22). Juvenile males also had lower ratios (1.93 ± 0.27) than adults (2.96 ± 1.41) and geriatrics (3.63 ± 1.59) (d’s = -1.32 to -0.99, P’s = 0.048 to < 0.0001), while adult and geriatric males were similar (d = -0.43 [95% CI: -1.08, 0.22], P = 0.20) (Figure 19B). No differences were observed between sexes within age groups (d’s = -0.41, 0.02, P = 0.51 to > 0.99) (Figure 19C).

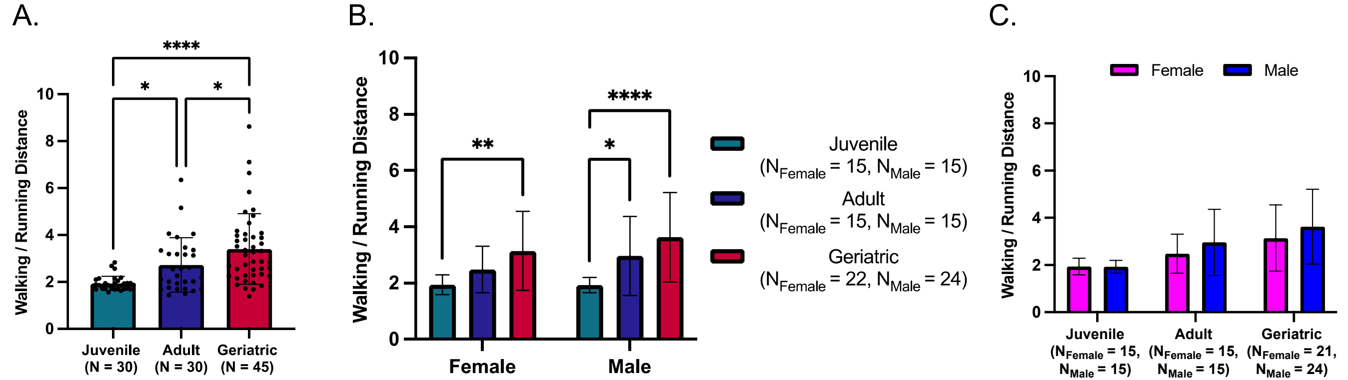
Among treated geriatric crickets, only the acarbose group exhibited elevated walking-to-running ratios (2.96 ± 1.25) compared to controls (2.19 ± 0.64; d = -0.75 [–1.40, –0.10], P = 0.04) (Figure 19D). Rapamycin (2.29 ± 0.73), phenylbutyrate (2.69 ± 0.90), and SLAM-treated crickets (2.62 ± 0.95) showed no differences from controls (d = -0.14 to -0.62, P’s = 0.26 to 0.99) (Figure 20D). When stratified by sex, these treatment effects did not persist (d’s = -0.89 to -0.14, P’s = 0.20 to > 0.99) (Figure 19E). No within-group sex differences were found across treatment cohorts (d’s = -0.26 to 0.81, P’s = 0.35 to > 0.99) (Figure 19F).

Relative to juveniles, all treatment groups, except for control and rapamycin groups (d’s = -0.87 to -0.55, P’s = 0.24 to 0.75), showed elevated walking-to-running ratios (d’s = -1.23 to -

1.05, *P*'s = 0.020 to 0.0002) (Figure 19G). Stratification by sex revealed that control and rapamycin females retained juvenile-like ratios (*d*'s = -0.53 to -0.48, *P*'s = 0.87 to 0.90), while phenylbutyrate-treated females trended lower (*d* = -0.95 [95% CI: -1.79, -0.11], *P* = 0.24), and all other treatment groups had elevated ratios compared to juvenile females (*d*'s = -1.40 to -1.20, *P*'s = 0.011 to 0.0093). Among males, only acarbose and phenylbutyrate-treated groups exhibited higher ratios (*d*'s = -1.45 to -1.16, *P*'s = 0.016 to 0.040) (Figure 19H). When compared to adults, no treatment group differed in walking-to-running ratios (*d*'s = -0.20 to 0.52, *P*'s = 0.26 to > 0.99), and this lack of difference was observed in both sexes (*d*'s = -0.54 to 0.68, *P*'s = 0.19 to > 0.99) (Figure 19I-J).

Compared to a historical geriatric cohort, both the current control and rapamycin-treated groups exhibited reduced walking-to-running distance ratios (*d*'s = 0.83 to 0.91, *P*'s = 0.0008 to 0.0019), while SLAM-treated crickets trended lower (*d* = 0.56 [95% CI: 0.03, 1.10], *P* = 0.055) (Figure 19K). This effect was sex-specific: in males, the control, rapamycin, and SLAM groups all exhibited reduced ratios compared to historical geriatrics (*d*'s = 0.89 to 1.05, *P*'s = 0.017 to 0.0044), while no differences were detected among females (*d*'s = 0.10 to 0.72, *P*'s = 0.17 to > 0.99) (Figure 19L).

In the overall analysis, crickets treated with rapamycin exhibited a trend toward increased walking-to-running distance ratios relative to pooled controls (*d* = 0.57 [95% CI: 0.06, 1.08], *P* = 0.057), while no discernible differences were observed for the other treatment groups (*d*'s = 0.06 to 0.31, *P*'s = 0.51 to > 0.99) (Figure 19M). Upon stratification by sex, none of the female treatment groups differed from female controls (*d*'s = -0.14 to 0.20, *P*'s = 0.96 to > 0.99), and a similar lack of difference was seen among males (*d*'s = 0.18 to 0.69, *P*'s = 0.10 to 0.94) (Figure 19N).



Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	1.30	2	0.65	0.47	0.63
Sex	2.59	1	2.59	1.87	0.18
Group	38.01	2	19.01	13.72	<0.0001
Residual	137.2	99	1.39		
Total	179.1	104			

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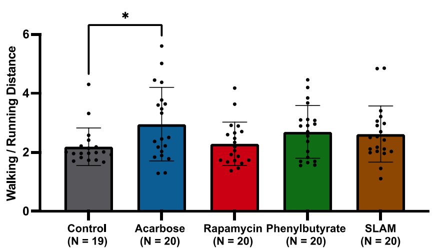

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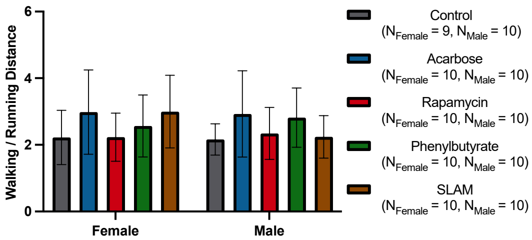

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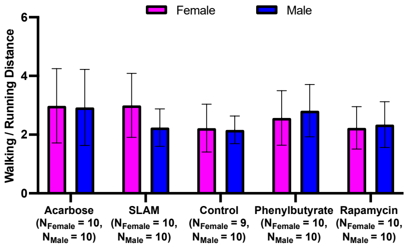
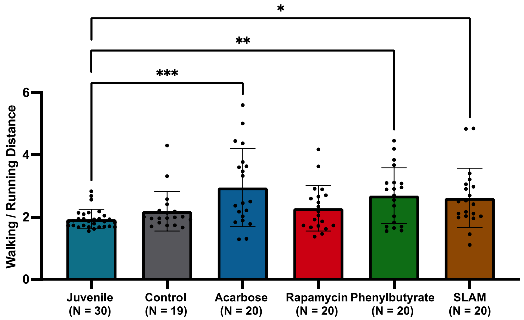


Source	SS	df	MS	F	*P*
Interaction	3.02	4	0.76	0.88	0.48
Sex	0.26	1	0.26	0.30	0.59
Group	7.59	4	1.90	2.21	0.074
Residual	76.27	89	0.86		
Total	87.14	98			

G.



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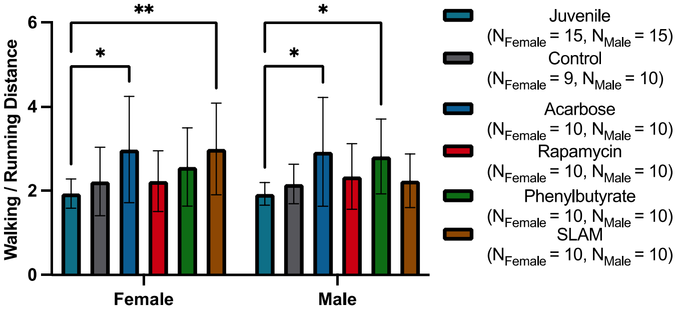

Source	SS	df	MS	F	*P*
Interaction	3.07	5	0.614	0.91	0.48
Sex	0.23	1	0.23	0.34	0.56
Group	16.46	5	3.29	4.88	0.0004
Residual	79.00	117	0.68		
Total	98.76	128			

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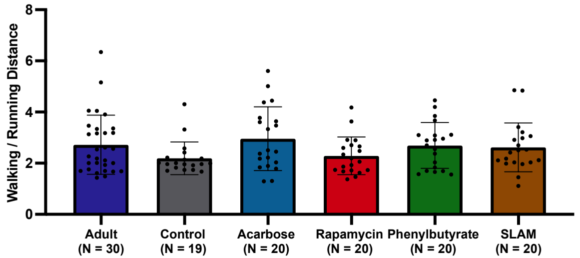

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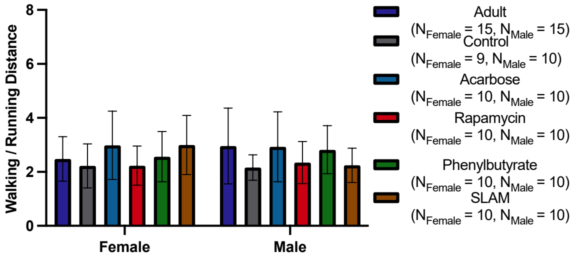
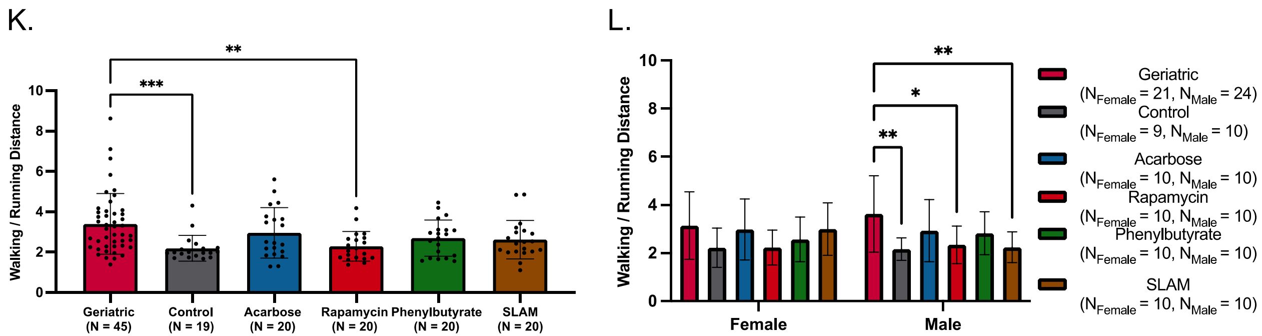
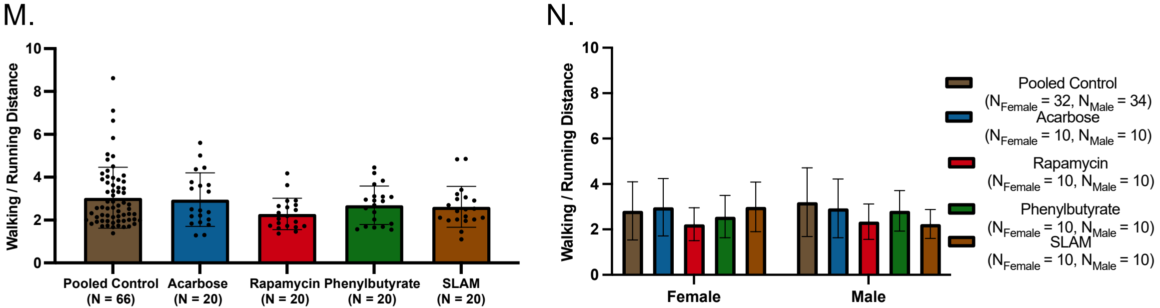


Source	SS	df	MS	F	*P*
Interaction	4.97	5	0.99	1.03	0.41
Sex	6.8e-04	1	6.8e-04	7.0e-04	0.98
Group	8.22	5	1.64	4.37	0.14
Residual	113.4	117	0.97		
Total	126.6	128			



Source	SS	df	MS	F	*P*
Interaction	5.69	5	1.14	0.87	0.51
Sex	4.2e-04	1	4.2e-04	3.2e-04	0.99
Group	28.88	5	5.78	4.39	0.001
Residual	173.6	132	1.32		
Total	208.2	143			



Source	SS	df	MS	F	*P*
Interaction	5.20	4	1.299	0.91	0.46
Sex	5.2e-03	1	5.2e-03	3.7e-03	0.95
Group	9.54	4	2.386	1.66	0.16
Residual	195.0	136	1.434		
Total	209.7	145			

Figure 19. Age- and treatment-effects on walking-to-running distance ratios. (A) Walking-to-running distance ratios increased with age. **(B)** Age-related trends persisted in both sexes. **(C)** No sex differences within age cohorts. **(D)** Acarbose-treated crickets had higher ratios than controls. **(E)** Treatment effects did not persist when stratified by sex. **(F)** No within-group sex differences across treatment groups. **(G)** Compared to juveniles, all groups except control and rapamycin had higher walking-to-running ratios. **(H)** Stratified by sex, only acarbose and SLAM-treated crickets differed from juveniles. **(I)** No treatment group differed from adult cohort. **(J)** No sex differences across treatment groups compared to adults. **(K)** Control and rapamycin-treated groups had lower ratios than historical geriatrics. **(L)** This trend was male-specific: control, rapamycin, and SLAM-treated males had lower ratios. **(M)** Rapamycin-treated crickets showed a trend toward increased walking-to-running distance ratios compared to controls, whereas other treatments had no detectable effect. **(N)** Sex-stratified analysis revealed no treatment effects on walking-to-running distance ratio in either males or females (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ****$P < 0.0001$).

Rapamycin partially rescues age-related declines in walking-to-running time ratios. Compared to adult and juvenile cohorts, geriatric crickets displayed markedly elevated walking-to-running time ratios (15.37 ± 9.01 vs. 10.29 ± 6.07 and 6.86 ± 2.39, respectively; *d*'s = -1.18 to

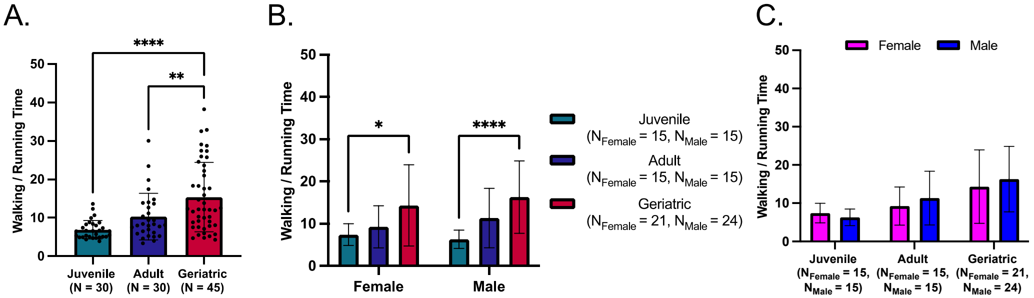
-0.64, P's = 0.006 to < 0.0001) (Figure 20A). Adults also trended higher than juveniles (d = –0.73 [95% CI: –1.26, –0.21], P = 0.13). When stratified by sex, juvenile females spent less time walking relative to geriatrics (7.40 ± 2.56 vs. 14.32 ± 9.60; d = -0.90 [95% CI: -1.59, -0.20], P = 0.01), with no difference observed relative to adult females (9.26 ± 4.97; d = -0.90 to -0.46 [95% CI: -1.18, 0.27], P = 0.74). Adult and geriatric females were also similar (d = -0.62 [95% CI: -1.29, 0.06], P = 0.08). Juvenile males demonstrated reduced walking/running time (6.32 ± 2.16) relative to geriatrics (16.29 ± 8.55; d = -1.42 [95% CI: -2.14, -0.70], P < 0.0001), and trended lower compared to adults (11.33 ± 7.02; d = -0.94 [95% CI: -1.69, -0.18], P = 0.12), with no difference between adults and geriatrics (d = -0.61 [95% CI: -1.27, 0.05], P = 0.08) (Figure 20B). Sex did not modulate the walking-to-running ratio within any cohort (d's = -0.33 to 0.44, P's > 0.99) (Figure 20C).

Walking-to running time ratios in the geriatric control group (10.8 ± 4.6) were similar to those observed in acarbose (13.8 ± 8.1), rapamycin (10.1 ± 5.0), phenylbutyrate (14.2 ± 8.5), and SLAM-treated crickets (11.3 ± 6.1) (d's = -0.48 to 0.14, P's = 0.32-0.99) (Figure 20D). These results were unchanged when stratified by sex (d's = -0.76 to 0.39, P's = 0.63 to > 0.99) (Figure 20E), and no sex differences were present within any treatment group (d's = -0.13 to 0.66, P's = 0.89 to > 0.99) (Figure 20F).

Compared to juvenile crickets, acarbose-, phenylbutyrate-, and SLAM-treated groups exhibited increased walking-to-running ratios (d's = -1.28 to -1.02, P's = 0.048 to 0.0002), while control and rapamycin groups remained indistinguishable from juveniles (d's = -1.14 to -0.87, P = 0.10 to 0.24) (Figure 20G). When stratified by sex, both females and males in the acarbose and phenylbutyrate groups showed elevated ratios relative to juveniles (d's = -1.97 to -1.01, P's = 0.021 to 0.011). Female rapamycin-treated crickets were comparable to juvenile females (d = -0.66 [95% CI: -1.48, 0.16], P = 0.84), while male rapamycin and control groups trended higher (d's = -1.25 to -0.99, P's = 0.34 to 0.45) (Figure 20H). No treatment group differed from adults (d's = -0.54 to 0.03, P's = 0.16 to > 0.99) (Figure 20I), a pattern that persisted across sexes (d's = -0.74 to 0.31, P's = 0.14 to > 0.99) (Figure 20J).

Compared to a prior geriatric cohort, rapamycin-treated crickets displayed lower walking-to-running time ratios (d = 0.65 [95% CI: 0.11, 1.19], P = 0.043), while SLAM-treated crickets trended lower (d = 0.57 [95% CI: 0.02, 1.11], P = 0.12) (Figure 20K). When stratified by sex, only males in the control and SLAM treated groups trended lower relative to historical controls (d's = 0.82 to 0.87, P's = 0.07 to 0.13) (Figure 20L).

Across the overall cohort, none of the treatment groups differed from pooled controls in walking-to-running time ratio (d's = -0.02 to 0.52, P's = 0.16 to > 0.99) (Figure 20M). Similarly, no differences were observed among females when compared to control females (d's = -0.15 to 0.51, P's = 0.47 to > 0.99), and male treatment groups likewise did not deviate from their respective controls (d's = 0.14 to 0.68, P's = 0.21 to 0.99) (Figure 20N).



Source	SS	df	MS	F	P
Interaction	51.15	2	25.58	0.54	0.59
Sex	24.81	1	24.81	0.52	0.47
Group	1339	2	669.6	14.05	<0.0001
Residual	4718	99	47.66		
Total	6133	104			

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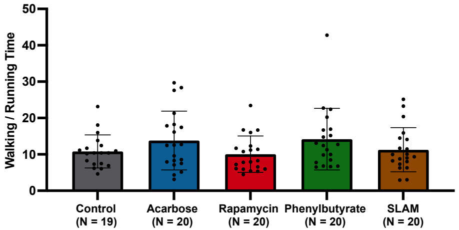

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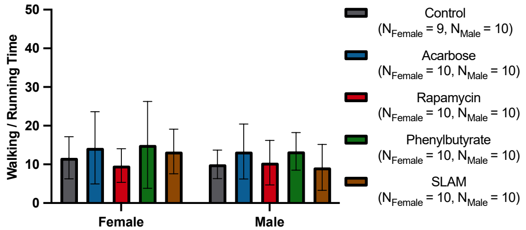

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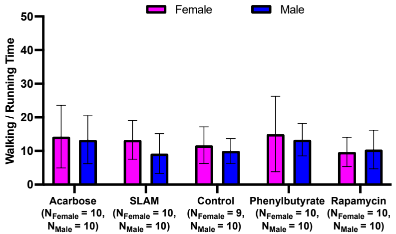

Source	SS	df	MS	F	*P*
Interaction	60.02	4	15.01	0.33	0.86
Sex	57.99	1	57.99	1.28	0.26
Group	271.8	4	67.95	1.50	0.21
Residual	4029	89	45.27		
Total	4419	98			

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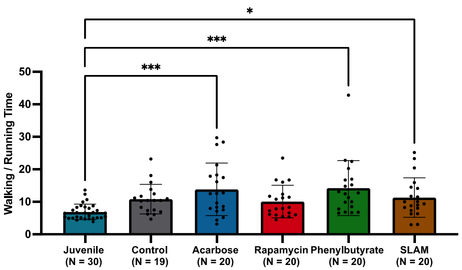

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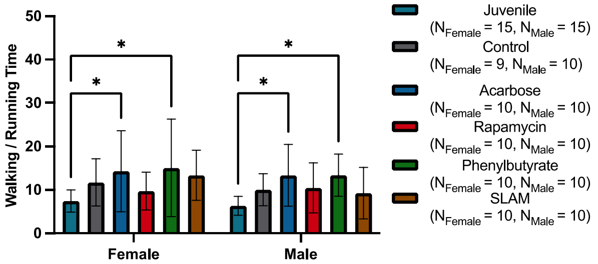

Source	SS	df	MS	F	*P*
Interaction	61.21	5	12.24	0.34	0.89
Sex	66.65	1	66.65	1.86	0.17
Group	893.0	5	178.6	4.99	0.0004
Residual	4186	117	35.78		
Total	5207	128			

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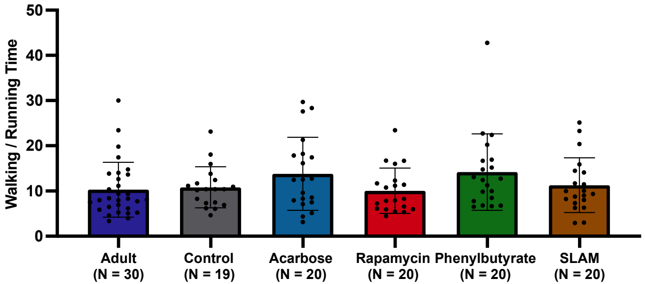

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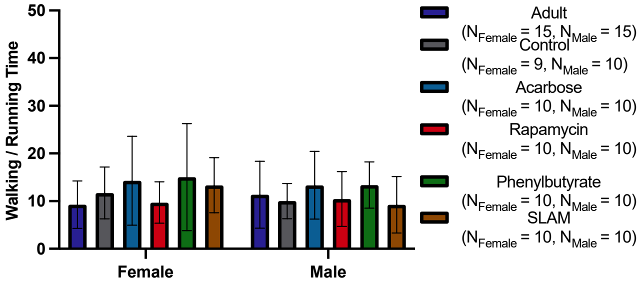
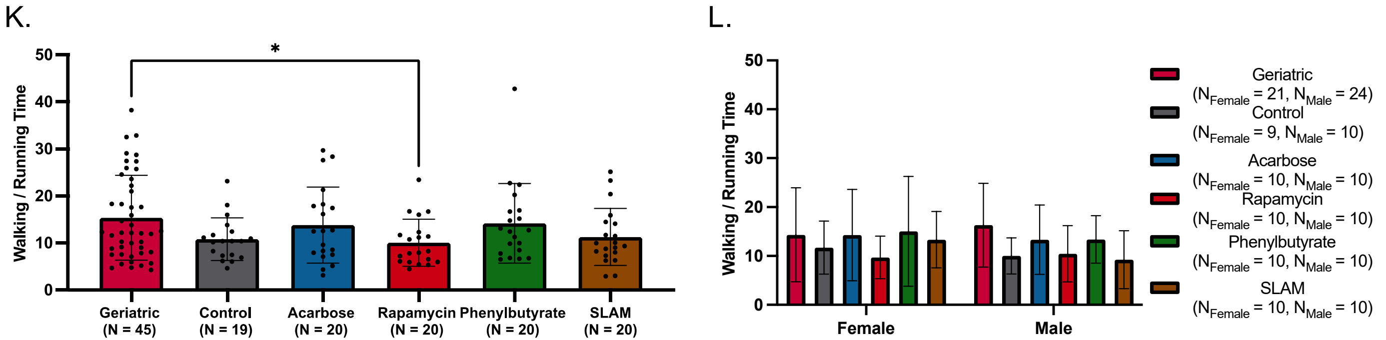
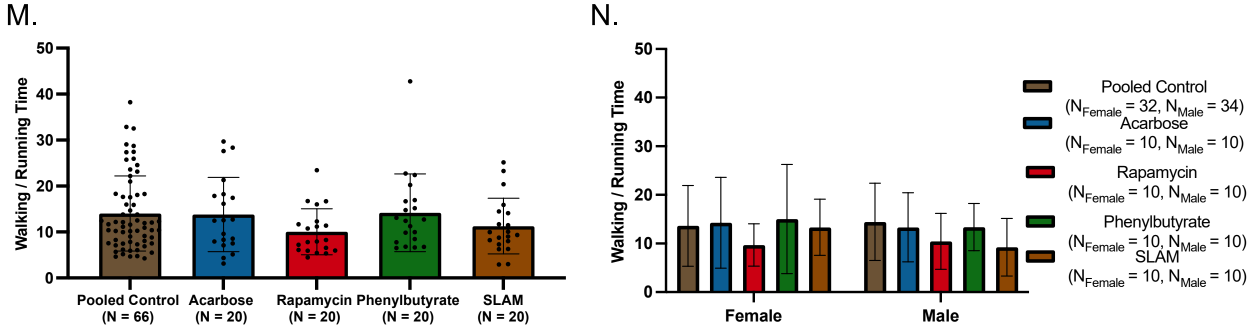


Source	SS	df	MS	F	*P*
Interaction	134.9	5	26.98	0.62	0.68
Sex	27.21	1	27.21	0.63	0.43
Group	343.0	5	68.61	1.59	0.17
Residual	5066	117	43.30		
Total	5571	128			



Source	SS	df	MS	F	*P*
Interaction	154.5	5	30.90	0.54	0.75
Sex	29.38	1	29.38	0.51	0.47
Group	598.4	5	119.7	2.09	0.07
Residual	7554	132	57.23		
Total	8336	143			



Source	SS	df	MS	F	*P*
Interaction	108.2	4	27.06	0.47	0.76
Sex	30.86	1	30.86	0.53	0.47
Group	342.9	4	85.72	1.48	0.21
Residual	7891	136	58.02		
Total	8373	145			

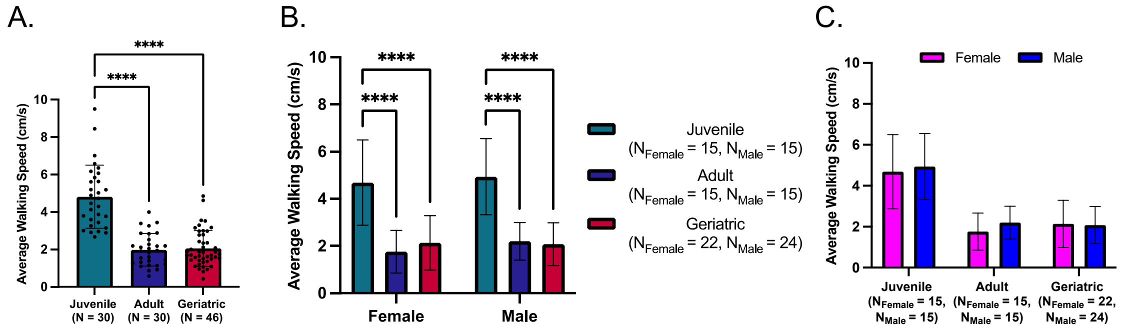
Figure 20. Age- and treatment effects on walking-to-running time ratio. (A) Geriatric crickets spent more time walking compared to running than adults and juveniles. **(B)** Geriatric males and females spent more time walking relative to juveniles. **(C)** No sex differences were detected within any age cohorts. **(D)** Walking-to-running time ratios were comparable across control and all treatment groups. **(E)** No treatment effects persisted when stratified by sex. **(F)** No within-group sex differences across treatments. **(G)** Compared to juveniles, only acarbose and phenylbutyrate groups had higher ratios. **(H)** This trend held in both males and females. **(I)** No treatment group differed from adult cohort. **(J)** Sex-stratified comparisons with adults showed no differences. **(K)** Rapamycin group had lower ratio compared to historical geriatrics. **(L)** No sex-specific effects observed in any group. **(M)** Walking-to-running time ratios remained consistent across all treatment groups relative to pooled controls. **(N)** No treatment effects on walking-to-running time ratio were detected in either sex following stratified analysis (**P* < 0.05, ***P* < 0.01, ****P* < 0.001, *****P* < 0.0001).

Rapamycin preserves juvenile-like walking speed in aged male crickets. Juvenile crickets exhibited higher average walking speeds than both adult and geriatric cohorts (4.81 ± 1.69 cm/s vs. 1.98 ± 0.87 and 2.05 ± 0.96 cm/s, respectively; *d*'s = 2.10 to 2.17, *P*'s < 0.0001), with no differences between adults and geriatrics (*d* = –0.07 [95% CI: –0.54, 0.39], *P* = 0.80) (Figure 21A). When stratified by sex, juvenile females walked faster than both adult and geriatric females (4.69 ± 1.81 cm/s vs. 1.76 ± 0.90 cm/s and 2.14 ± 1.15 cm/s, respectively; *d* = 1.99 to 1.71, *P*'s < 0.0001), while adult and geriatric females did not differ (*d* = -0.35 [95% CI: -1.02, 0.32], *P* = 0.63) (Figure 21B). Among males, juveniles also outpaced both adult and geriatric counterparts (4.94 ± 1.61 cm/s vs. 2.20 ± 0.79 cm/s and 2.08 ± 0.91 cm/s, respectively; *d* = 2.10 to 2.29, *P*'s < 0.0001), with no differences between adults and geriatrics (*d* = 0.14 [95% CI: -0.51, 0.78], *P* = 0.95). No sex-based differences in walking speed were observed within any age group (*d*'s = -0.51 to 0.06, *P*'s = 0.97 to > 0.99) (Figure 21C).

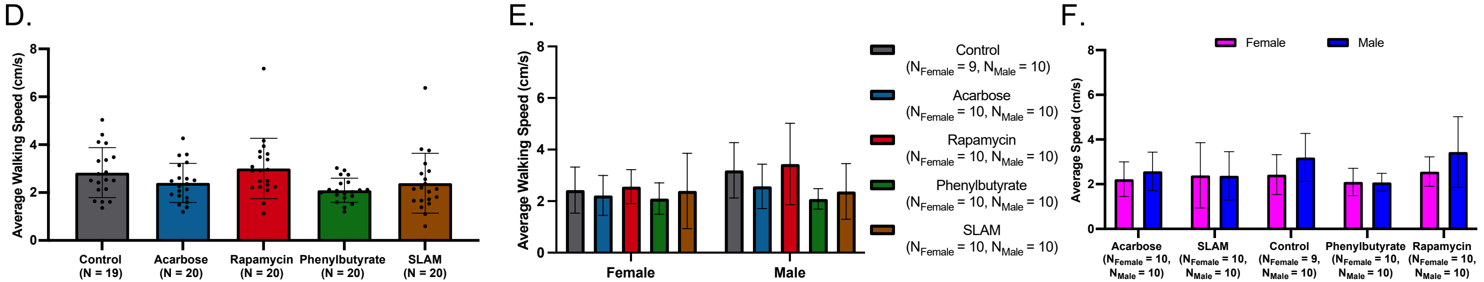
Among geriatric crickets, average walking speed did not differ across treatment groups (control: 2.83 ± 1.04 cm/s; acarbose: 2.40 ± 0.82 cm/s; rapamycin: 3.00 ± 1.26 cm/s; SLAM: 2.39 ± 1.25 cm/s; *d*'s = -0.14 to 0.45, *P*'s = 0.45 to 0.96). Only phenylbutyrate-treated crickets (2.09 ± 0.50 cm/s) trended slower than controls (*d* = 0.90, [95% CI: 0.24, 1.55], *P* = 0.08) (Figure 21D). When stratified by sex, this pattern persisted in both female and males (*d*'s = -0.16 to 0.73, *P*'s = 0.21 to > 0.99), with phenylbutyrate-treated males trending slower (*d* = 1.32 [95% CI: 0.35, 2.28], *P* = 0.05) (Figure 21E). No within-treatment sex differences were detected (*d*'s = -0.74 to 0.02, *P*'s = 0.27 to > 0.99) (Figure 21F).

Relative to juveniles, all geriatric groups, including the control, exhibited slower walking speeds (*d*'s = 1.16 to 1.98, *P*'s < 0.0001) (Figure 21G). These reductions were consistent across both sexes (*d*'s = 0.91 to 2.15, *P*'s = 0.0002 to < 0.0001) (Figure 21H). When compared to adults, both control and rapamycin-treated geriatrics exhibited elevated walking speeds (*d*'s = -0.96 to -0.89, *P*'s = 0.0021 to 0.017), while crickets treated with acarbose, phenylbutyrate, or SLAM did not differ from adults (*d*'s = -0.49 to -0.15, *P*'s = 0.50 to > 0.99) (Figure 21I). Sex-stratified analyses revealed that only rapamycin-treated males maintained walking speeds above adult males (*d* = -1.03 [95% CI: -1.88, -0.18], *P* = 0.010), while rapamycin-treated females and male controls trended similarly without reaching statistical thresholds (*d*'s = -1.06 to -0.95, *P*'s = 0.06 to 0.17) (Figure 21J). Compared to a historical geriatric cohort, both control and rapamycin-treated groups demonstrated enhanced walking speeds (*d*'s = -0.89 to -0.78, *P*'s = 0.0024 to 0.022) (Figure 21K). This enhancement was retained exclusively in males (*d*'s = -1.17 to -1.14, *P*'s = 0.02 to 0.0024) (Figure 21L).

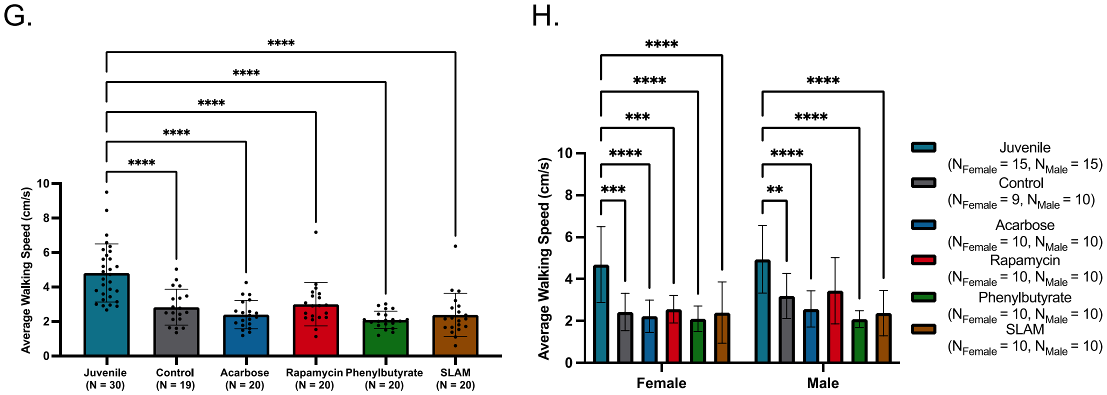
In the overall analysis, rapamycin-treated crickets displayed faster average walking speeds relative to pooled controls (*d* = -0.65 [95% CI: -1.16, -0.14], *P* = 0.025), while the other treatment groups showed no meaningful differences (*d*'s = -0.12 to 0.20, *P*'s = 0.92 to 0.98) (Figure 21M). When stratified by sex, no female treatment group differed from female controls (*d*'s = -0.17 to 0.10, *P*'s = 0.97 to > 0.99). In contrast, rapamycin-treated males exhibited higher average walking speeds compared to control males (*d* = -0.84 [95% CI: -1.58, -0.11], *P* = 0.024), whereas other male groups did not differ from controls (*d*'s = -0.15 to 0.32, *P*'s = 0.84 to 0.98) (Figure 21N).



Source	SS	df	MS	F	*P*
Interaction	1.20	2	0.60	0.40	0.67
Sex	1.14	1	1.14	0.76	0.39
Group	163.1	2	81.53	54.49	<0.0001
Residual	148.1	99	1.50		
Total	313.54	104			



Source	SS	df	MS	F	*P*
Interaction	3.54	4	0.89	0.88	0.48
Sex	3.80	1	3.80	3.77	0.055
Group	10.53	4	2.63	2.62	0.040
Residual	89.51	89	1.01		
Total	107.38	98			



Source	SS	df	MS	F	*P*
Interaction	3.64	5	0.73	0.50	0.79
Sex	4.28	1	4.28	2.92	0.09
Group	130.0	5	25.99	17.71	<0.0001
Residual	171.7	117	1.47		
Total	309.62	128			

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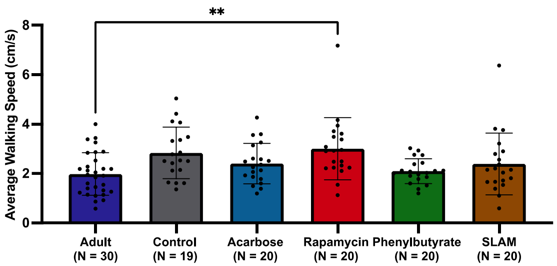

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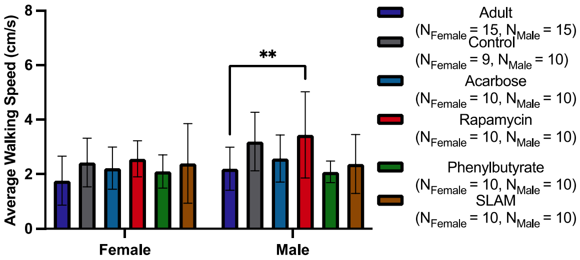

Source	SS	df	MS	F	*P*
Interaction	3.56	5	0.71	0.76	0.58
Sex	5.04	1	5.04	5.37	0.022
Group	17.67	5	3.54	3.77	0.0034
Residual	109.8	117	0.94		
Total	132.87	128			

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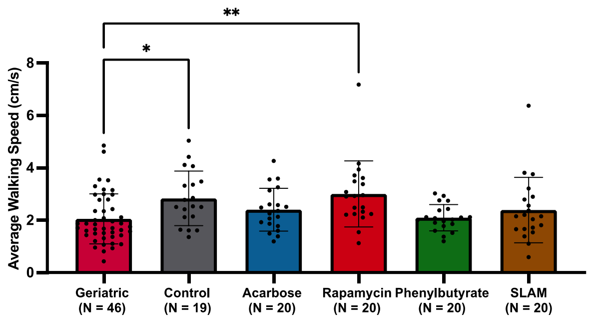

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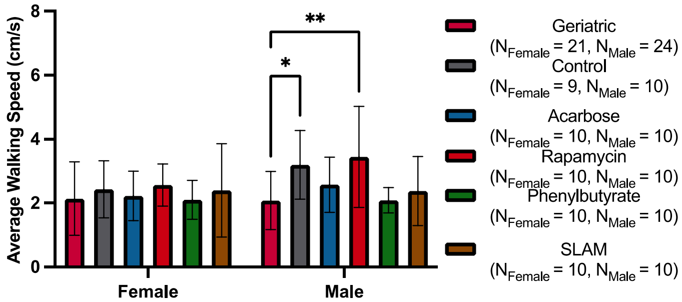
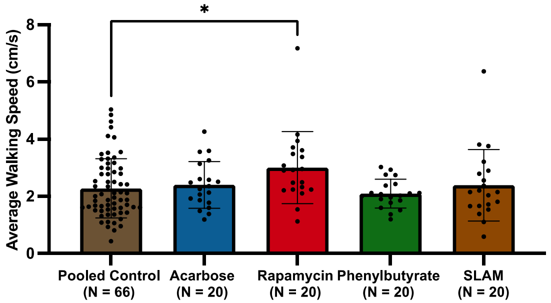


Source	SS	df	MS	F	*P*
Interaction	5.09	5	1.02	0.99	0.42
Sex	3.28	1	3.28	3.20	0.076
Group	16.16	5	3.23	3.16	0.010
Residual	135.2	132	1.02		
Total	159.73	143			

M.



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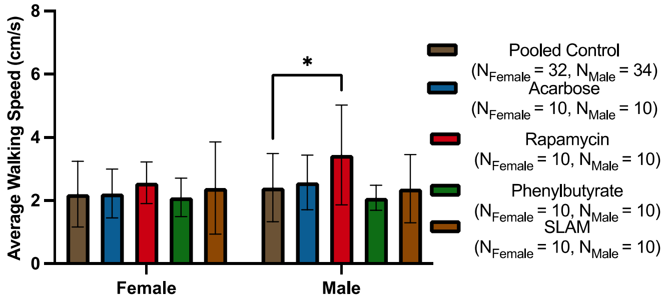


Source	SS	df	MS	F	*P*
Interaction	2.77	4	0.69	0.65	0.63
Sex	2.28	1	2.28	2.14	0.15
Group	9.75	4	2.44	2.29	0.063
Residual	144.8	136	1.07		
Total	159.6	145			

Figure 21. Age- and treatment-effect on average walking speed. (A) Juveniles walked faster than adults and geriatrics. **(B)** Age-related locomotor decline was observed in both sexes. **(C)** No sex differences emerged within any age cohort. **(D)** Walking speeds were comparable across geriatric treatment groups, except phenylbutyrate, which trended slower. **(E)** These patterns persisted in sex-stratified analyses, with slower walking in phenylbutyrate-treated males. **(F)** No sex differences were detected within treatment groups. **(G)** All geriatric groups walked slower than juveniles. **(H)** This effect was evident in both sexes, though rapamycin-treated males trended faster. **(I)** Geriatric control and rapamycin groups outpaced adults. **(J)** Only rapamycin-treated males exceeded adult male speeds. **(K)** Control and rapamycin-treated geriatric crickets surpassed historical controls. **(L)** This enhancement was specific to males in both groups. **(M)** Rapamycin-treated crickets showed elevated average walking speeds compared to pooled controls. **(N)** Sex-stratified analysis revealed a walking speed enhancement in rapamycin-treated males, with no differences among female groups (*P < 0.05, **P < 0.01, ***P < 0.001, ****P < 0.0001).

Rapamycin preserves juvenile-like running speeds in aged male crickets. Average running speed declined with age, with juvenile crickets exhibiting the fastest performance (33.77 ± 8.63 cm/s), followed by adults (19.92 ± 12.06 cm/s) and geriatrics (18.99 ± 7.77 cm/s), which did not differ from one another (juvenile vs. adult/geriatric: d‘s = 1.30 to 1.80, P‘s < 0.0001; adult vs. geriatric: d = 0.09 [95% CI: –0.37, 0.56], P = 0.91) (Figure 22A). This age-related decline was evident in both sexes. Juvenile females (35.28 ± 10.66 cm/s) outpaced adult (19.29 ± 13.95 cm/s) and geriatric counterparts (18.26 ± 8.17 cm/s) (d’s = 1.25 to 1.79, P’s < 0.0001), while juvenile males (32.27 ± 5.99 cm/s) similarly outperformed adult (20.54 ± 10.29 cm/s) and geriatric cohorts (19.55 ± 7.78 cm/s) (d’s = 1.36 to 1.74, P’s = 0.0031 to 0.0003). No differences were detected between adults and geriatrics of either sex (d‘s = 0.09 to 0.11, P‘s = 0.95) (Figure 22B). Within each age group, average running speed did not differ by sex (d’s = -0.16 to 0.34, P’s > 0.99) (Figure 22C).

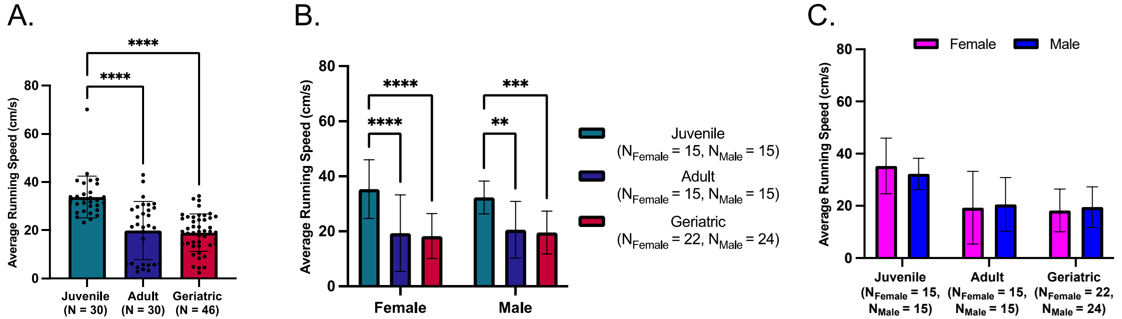
Drug treatment influenced average running speed in geriatric cohorts. Control crickets (27.9 ± 5.9 cm/s) outpaced those treated with acarbose (22.7 ± 5.2 cm/s) and SLAM groups (22.2 ± 7.8 cm/s) (d’s = 0.80 to 0.92, P’s = 0.04 to 0.02), whereas rapamycin-treated individuals (29.2 ± 6.7 cm/s) ran comparably to controls (d = -0.20 [–0.83, 0.43], P = 0.90). Phenylbutyrate-treated crickets exhibited a trend toward lower speed relative to controls (23.1 ± 5.3 cm/s; d = 0.84 [95% CI: 0.18, 1.49], P = 0.06) (Figure 22D). When stratified by sex, no treatment differences emerged in either males or females (d’s = -0.53 to 0.90, P’s = 0.08 to > 0.99), except for phenylbutyrate-treated males, who showed a trend toward lower performance (d = 1.25 [95% CI: 0.29, 2.21], P = 0.09) (Figure 22E). Within-group sex comparisons across treatments remained nonsignificant (d’s = -0.63 to 0.36, P’s = 0.64 to > 0.99) (Figure 22F).

Relative to juveniles, all treatment groups demonstrated reduced running speeds (d’s = 0.75 to 1.46, P’s = 0.020 to < 0.0001), except for rapamycin-treated crickets, whose performance was statistically indistinguishable from juveniles (d = 0.57 [95% CI: -0.01, 1.14], P = 0.10) (Figure 22G). Stratification by sex revealed this preservation was male specific: both rapamycin-treated and control males retained juvenile-like performance (d’s = 0.14 to 0.70, P’s = 0.55 to > 0.99), while all other male treatment groups had reduced speeds (d’s = 1.29 to 1.70, P’s = 0.026 to 0.0021). In contrast, all female treatment groups exhibited lower speeds than juvenile females (d’s = 0.80 to 1.53, P’s = 0.03 to < 0.0001) (Figure 22H). Compared to adult crickets, both control and rapamycin-treated geriatrics exhibited elevated running speeds (d’s = -0.77 to -0.89, P’s = 0.0044 to 0.0005), whereas other treatment groups did not differ from adults (d’s = -0.31 to 0.21, P’s = 0.54 to 0.82) (Figure 22I). This enhancement was sex-specific: only rapamycin-treated males outperformed their adult counterparts (d = -1.17 [95% CI: -2.03, -0.31], P = 0.007), while control males trended higher (d = -0.90 [95% CI: -1.74, -0.06], P = 0.08).

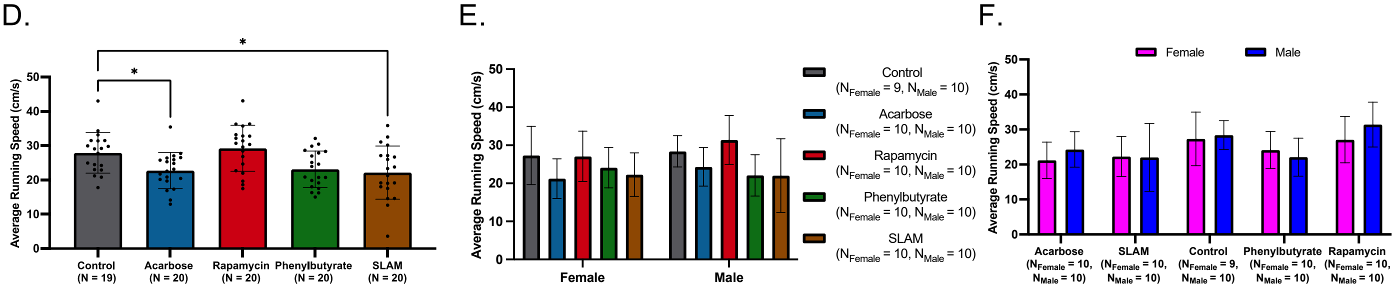
No female treatment group exceeded adult female performance (*d*'s = -0.64 to -0.16, *P*'s = 0.09 to 0.98) (Figure 22J).

When benchmarked against a historical geriatric cohort, both control and rapamycin-treated groups demonstrated higher running speeds (*d*'s = -1.35 to -1.21, *P*'s < 0.0001), with phenylbutyrate-treated individuals trending higher (*d* = -0.57 [95% CI: -1.11, -0.03], *P* = 0.11) (Figure 22K). This enhancement remained robust in both males and females for the control and rapamycin-treated groups (*d*'s = -1.56 to -1.10, *P*'s = 0.006 to < 0.0001) (Figure 22L).

In the overall cohort, rapamycin-treated crickets exhibited higher average running speeds than pooled controls (*d* = -0.95 [95% CI: -1.47, -0.43], *P* = 0.0003), while the remaining treatment groups did not differ from controls (*d*'s = -0.19 to -0.07, *P*'s = 0.87 to > 0.99) (Figure 22M). When stratified by sex, none of the female treatment groups showed differences in average running speed compared to controls (*d*'s = -0.35 to 0.01, *P*'s = 0.71 to > 0.99). Among males, rapamycin treatment was associated with faster running speeds (*d* = -1.18 [95% CI: -1.93, -0.43], *P* = 0.0026), while other male groups remained comparable to controls (*d*'s = -0.28 to 0.02, *P*'s = 0.88 to >0.99) (Figure 22N).

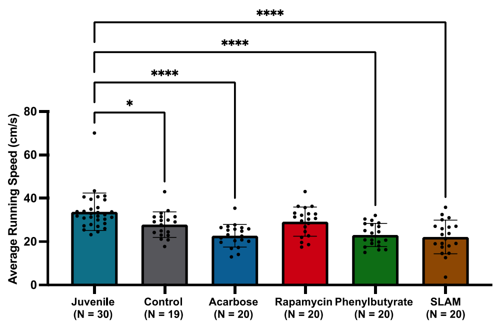


Source	SS	df	MS	F	*P*
Interaction	98.19	2	0.63	0.54	0.59
Sex	0.63	1	49.10	0.007	0.93
Group	4497	2	2248	24.66	<0.0001
Residual	9027	99	91.18		
Total	13623	104			



Source	SS	df	MS	F	*P*
Interaction	129.5	4	32.38	0.82	0.52
Sex	38.38	1	38.38	0.97	0.33
Group	849.4	4	212.4	5.37	0.0006
Residual	3520	89	39.55		
Total	4537.3	98			

G.



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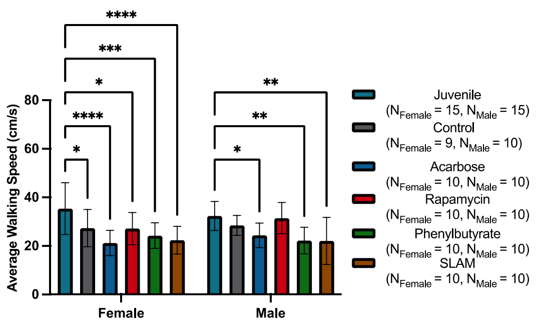

Source	SS	df	MS	F	*P*
Interaction	233.9	5	46.78	0.97	0.44
Sex	9.05	1	9.048	0.19	0.66
Group	2626	5	525.1	10.94	<0.0001
Residual	5614	117	47.99		
Total	8483	128			

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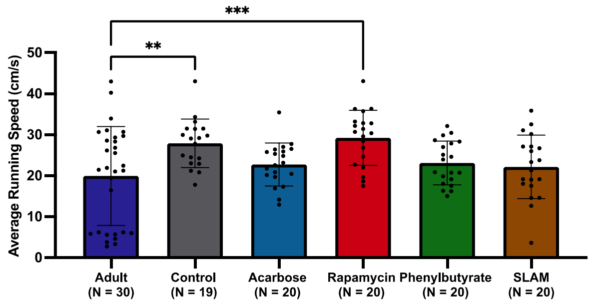

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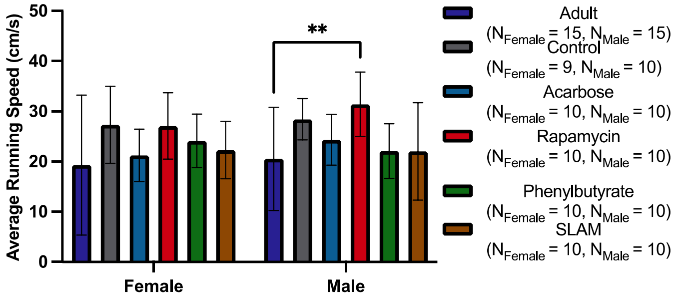
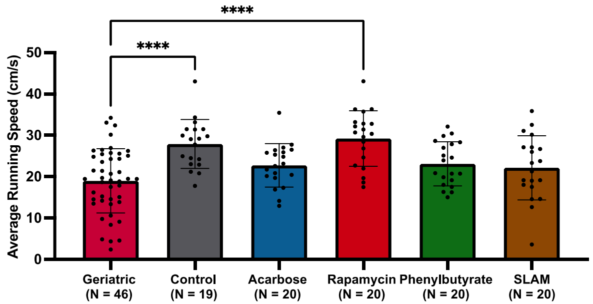


Source	SS	df	MS	F	*P*
Interaction	129.5	5	25.90	0.39	0.85
Sex	48.87	1	48.87	0.74	0.39
Group	1442	5	288.3	4.37	0.0011
Residual	7725	117	66.03		
Total	9345	128			

K.



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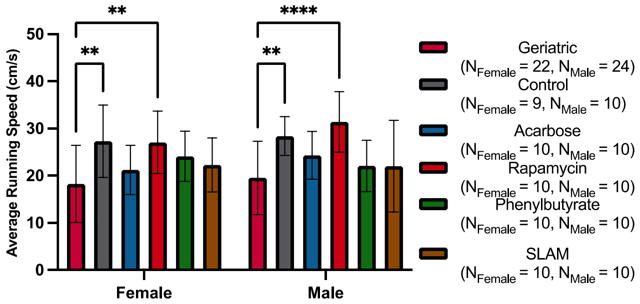
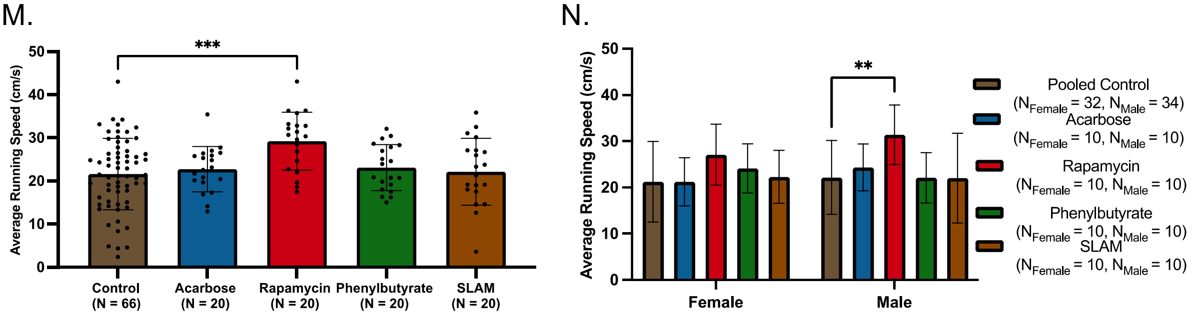


Source	SS	df	MS	F	*P*
Interaction	129.5	5	25.91	0.55	0.74
Sex	51.33	1	51.33	1.08	0.30
Group	1991	5	398.2	8.41	<0.0001
Residual	6248	132	47.34		
Total	8420	143			



Source	SS	df	MS	F	*P*
Interaction	130.6	4	32.64	0.60	0.66
Sex	42.51	1	42.51	0.79	0.38
Group	902.0	4	225.5	4.17	0.0032
Residual	7353	136	54.06		
Total	8428	145			

Figure 22. Age- and treatment-effects on average running speed. (A) Juveniles ran faster than adults and geriatrics. **(B)** This age-related trend was preserved in both sexes. **(C)** No within-group sex differences across age cohorts. **(D)** Acarbose and combined treatment groups had reduced speed compared to control. **(E)** No treatment effects when stratified by sex. **(F)** No within-group sex differences in any treatment group. **(G)** All treatment groups ran slower than juveniles, except rapamycin. **(H)** Rapamycin-treated and control males matched juvenile males; all females were slower than juveniles. **(I)** Control and rapamycin-treated groups ran faster than adults. **(J)** Only rapamycin-treated males outperformed adult males. **(K)** Control and rapamycin-treated groups exceeded historical geriatric cohort in speed. **(L)** This trend held true in both males and females. **(M)** Rapamycin treatment increased average running speed in the overall cohort, with no effects observed in other groups. **(N)** Rapamycin elevated running speed in males but had no detectable impact in females (**P* < 0.05, ***P* < 0.01, ****P* < 0.001, *****P* < 0.0001).

Geriatric crickets exhibit age-associated avoidance of the central arena, with selective restoration of exploratory behavior by treatment and sex. Geriatric crickets displayed lower central-to-peripheral distance ratios (0.24 ± 0.22) compared to both adult (1.04 ± 1.36) and juveniles (0.87 ± 0.80), (*d*'s = 0.91 to 1.17, *P*'s = 0.007 to 0.0004), while adults did not differ from juveniles (*d* = -0.15 [95% CI: -0.66, 0.36], *P* = 0.72) (Figure 23A).

This decline was preserved across sexes. Adult females (0.97 ± 1.13) showed elevated ratios relative to geriatric females (0.25 ± 0.26; *d* = 0.94 [95% CI: 0.24, 1.63], *P* = 0.04), but did not differ from juvenile females (0.89 ± 0.96; *d* = -0.07 [95% CI: -0.79, 0.64], *P* = 0.97). Juvenile and geriatric females also did not differ (*d* = 0.97 [95% CI: 0.27, 1.67], *P* = 0.08) (Figure 23B). A similar trend was observed in males: adults (1.12 ± 1.59) outperformed geriatrics (0.24 ± 0.18; *d* = 0.87 [95% CI: 0.20, 1.55], P = 0.008), while juveniles (0.86 ± 0.64) did not differ from adults (*d* = -0.21 [95% CI: -0.93, 0.51], *P* = 0.69) but trended higher than geriatrics (*d* = 1.45 [95% CI: 0.73, 2.17], *P* = 0.08). No sex differences were observed within any age group (*d*'s = -0.11 to 0.03, *P*'s > 0.99) (Figure 23C).

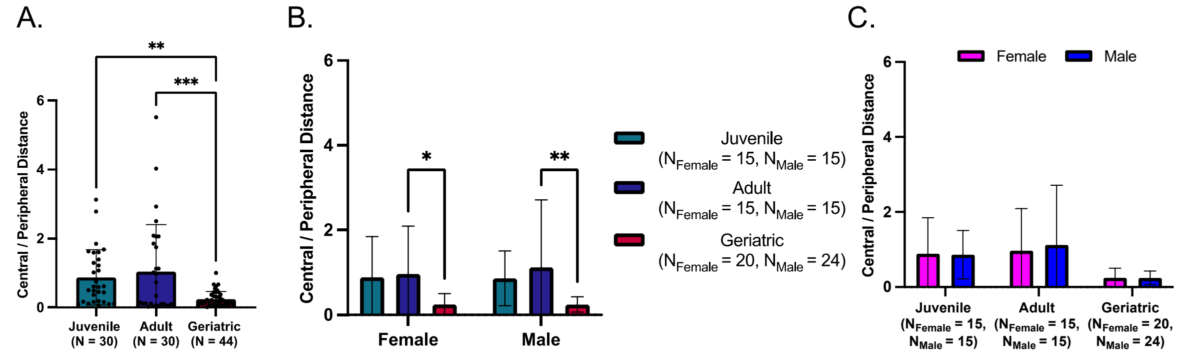
Treatment effects were modest overall. While acarbose-treated individuals (0.26 ± 0.40) trended lower than geriatric controls (0.51 ± 0.25; *d* = 0.73 [95% CI: 0.08, 1.38], *P* = 0.27), no other treatment group differed from controls (*d*'s = -0.14 to 0.37, *P*'s = 0.18 to 0.96) (Figure 23D). Upon sex stratification, phenylbutyrate-treated males (*d* = 0.94 [95% CI: 0.02, 1.87], *P* = 0.58) and acarbose-treated females (*d* = 1.83 [95% CI: 0.76, 2.90], *P* = 0.29) both trended lower relative to controls, although no other male or female treatment groups differed (*d*'s = -0.72 to

0.67, *P*'s = 0.11 > 0.99) (Figure 23E). Notably, phenylbutyrate-treated females exhibited higher central-to-peripheral ratios than their male counterparts (*d* = 0.94 [95% CI: -0.09, 1.86], *P* = 0.035), a difference absent in all other treatment groups (*d*'s = -0.75 to 0.31, *P*'s = 0.40 to > 0.99) (Figure 23F).

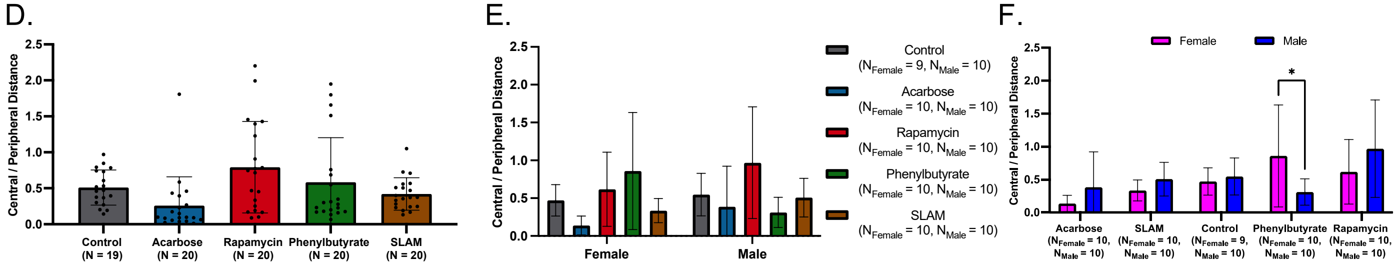
Relative to juvenile crickets, central exploration was reduced in the acarbose- and SLAM-treated groups (*d*'s = 0.69 to 0.90, *P*'s = 0.027 to 0.0011), but preserved in rapamycin, phenylbutyrate and control cohorts (*d*'s = 0.11 to 0.55, *P*'s = 0.12 to 0.99) (Figure 23G). This pattern was sex-dependent: acarbose-treated females differed from juvenile females (*d* = 0.96 [95% CI: 0.12, 1.81], *P* = 0.006), whereas no male treatment group differed from juvenile males (*d*'s = -0.16 to 0.77, *P*'s = 0.15 to 0.99), though phenylbutyrate-treated males trended lower (*d* = 1.03 [95% CI: 0.18, 1.88], *P* = 0.07) (Figure 23H). Compared to adult crickets, both acarbose- and SLAM-treated groups exhibited lower central-to-peripheral ratios (*d*'s = 0.57 to 0.71, *P*'s = 0.028 to 0.0030) (Figure 23I). This effect was again sex-dependent, emerging only in females: acarbose-treated females had reduced ratios compared to adult females (*d* = 0.91 [95% CI: 0.07, 1.75], *P* = 0.045), while no male treatment group showed differences (*d*'s = 0.11 to 0.63, *P*'s = 0.053 to > 0.99) (Figure 23J).

In comparisons with a historical geriatric cohort, rapamycin- and phenylbutyrate-treated crickets showed higher central-to-peripheral ratios (*d*'s = -1.37 to -0.87, *P*'s = 0.0098 to < 0.0001). SLAM and control groups also trended higher (*d*'s = -1.16 to -0.80, *P*'s = 0.076 to 0.39), while acarbose-treated individuals did not differ (*d* = -0.07 [95% CI: -0.60, 0.46], *P* > 0.99) (Figure 23K). These effects varied by sex: phenylbutyrate-treated females exhibited enhanced central exploratory behavior compared to historical geriatric females (*d* = -1.24 [95% CI: -2.05, -0.42], *P* = 0.0004), with trends observed in control and rapamycin groups (*d*'s = -1.04 to -0.87, *P*'s = 0.06 to 0.50). Among males, rapamycin-treated individuals outperformed historical geriatrics (*d* = -1.69 [95% CI: -2.53, -0.85], *P* = < 0.0001), with SLAM and control groups trending higher as well (*d*'s = -1.42 to -1.28, *P*'s = 0.16 to 0.28) (Figure 23L).

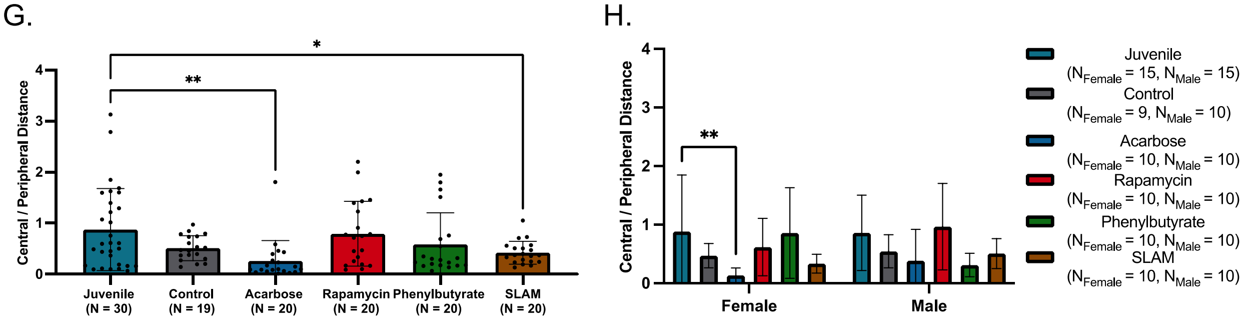
In the overall cohort, rapamycin-treated crickets exhibited greater central exploratory behavior, covering more distance in the center relative to the periphery compared to pooled controls (*d* = -1.22 [95% CI: -1.76, -0.68], *P* < 0.0001). Phenylbutyrate-treated crickets showed a similar trend toward increased central distance (*d* = -0.69 [95% CI: -1.20, -0.18], *P* = 0.054), while the remaining treatment groups did not differ from controls (*d*'s = 0.22 to -0.38, *P*'s = 0.82 to 0.95) (Figure 23M). When stratified by sex, phenylbutyrate-treated females spent more distance in the center relative to the periphery than control females (*d* = -1.19 [95% CI: -1.95, -0.42], *P* = 0.001), with rapamycin-treated females showing a similar trend (*d* = -0.88 [95% CI: -1.63, -0.13], *P* = 0.15); other female treatment groups did not differ (*d*'s = 0.75 to -0.08, *P*'s = 0.58 to > 0.99). Among males, rapamycin-treated individuals demonstrated increased central relative to peripheral distance (*d* = -1.54 [95% CI: -2.32, -0.77], *P* < 0.0001), whereas the remaining male groups showed no differences from controls (*d*'s = -0.15 to 0.08, *P*'s = 0.59 to > 0.99) (Figure 23N).



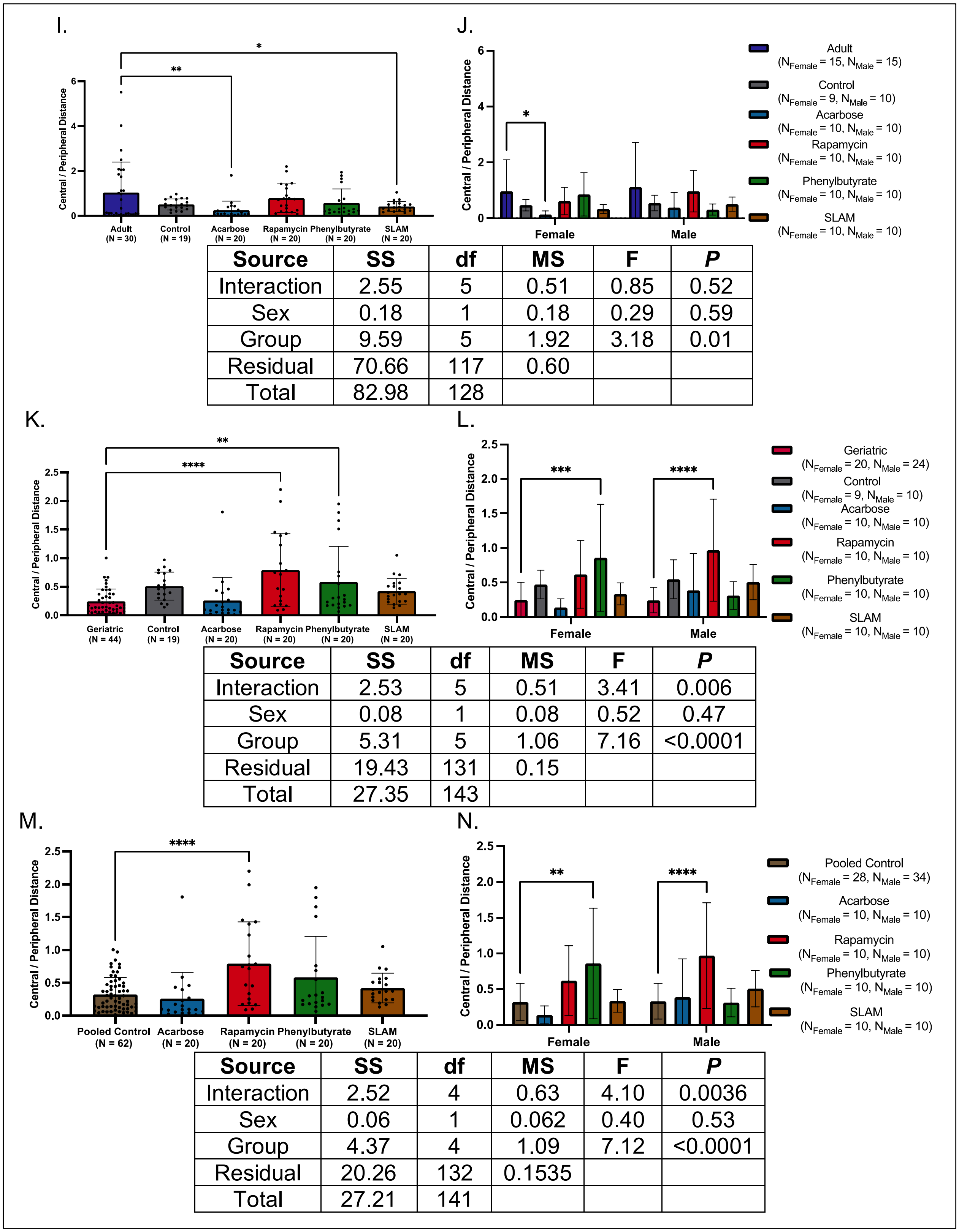
Source	SS	df	MS	F	*P*
Interaction	0.15	2	0.08	0.10	0.91
Sex	0.04	1	0.04	0.06	0.81
Group	13.31	2	6.67	8.82	0.0003
Residual	73.98	99	0.75		
Total	87.48	104			



Source	SS	df	MS	F	*P*
Interaction	2.50	4	0.63	3.20	0.02
Sex	0.09	1	0.087	0.44	0.51
Group	3.12	4	0.78	3.99	0.005
Residual	17.42	89	0.20		
Total	23.13	98			



Source	SS	df	MS	F	*P*
Interaction	2.54	5	0.51	1.65	0.15
Sex	0.06	1	0.06	0.21	0.65
Group	6.11	5	1.22	3.95	0.0024
Residual	36.16	117	0.31		
Total	44.87	128			



Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	2.55	5	0.51	0.85	0.52
Sex	0.18	1	0.18	0.29	0.59
Group	9.59	5	1.92	3.18	0.01
Residual	70.66	117	0.60		
Total	82.98	128			

Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	2.53	5	0.51	3.41	0.006
Sex	0.08	1	0.08	0.52	0.47
Group	5.31	5	1.06	7.16	<0.0001
Residual	19.43	131	0.15		
Total	27.35	143			

Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	2.52	4	0.63	4.10	0.0036
Sex	0.06	1	0.062	0.40	0.53
Group	4.37	4	1.09	7.12	<0.0001
Residual	20.26	132	0.1535		
Total	27.21	141			

Figure 23. Age- and treatment-effects of central-to-peripheral distance ratios. (A) Geriatric crickets showed slower central-to-peripheral distance ratios than both adults and juveniles,

while adult and juvenile exploration did not differ. **(B)** Age-related declines in central exploration were preserved across sexes. **(C)** No sex differences were observed within any age group. **(D)** Treatment effects were modest; no group differed from geriatric controls, though acarbose-treated individuals trended lower. **(E)** Sex-stratified analysis revealed trends toward reduced exploration in phenylbutyrate-treated males and acarbose-treated females. **(F)** Phenylbutyrate-treated females exhibited higher ratios than males, an effect absent in other treatment groups. **(G)** Central exploration was reduced in acarbose- and SLAM-treated crickets compared to juveniles, while rapamycin, phenylbutyrate, and control groups were comparable. **(H)** Acarbose-treated females had lower ratios than juvenile females while no male group differed from juvenile males. **(I)** Acarbose- and SLAM-treated groups exhibited reduced exploration compared to adults. **(J)** Only acarbose-treated females differed from adult females. **(K)** Rapamycin- and phenylbutyrate-treated groups had higher ratios than historical geriatrics, while SLAM and control groups trended higher. **(L)** Phenylbutyrate improved central exploration in females; rapamycin improved exploration in males; SLAM and control groups trended higher. **(M)** Rapamycin and phenylbutyrate treatments enhanced central exploratory distance relative to periphery in the overall cohort. **(N)** Males responded to rapamycin with increased central exploration, while females showed a similar trend under phenylbutyrate (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ****$P < 0.0001$).

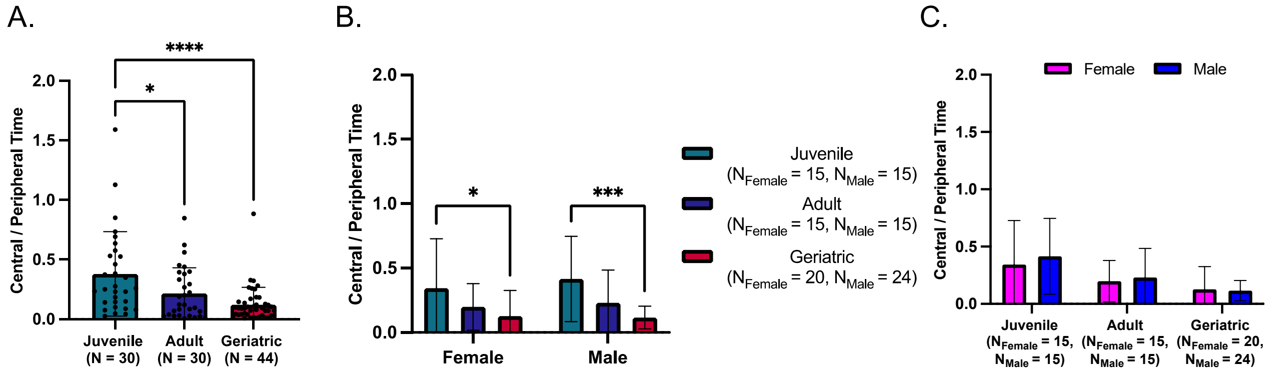
Aging reduces time spent in the central arena, selectively rescued by rapamycin and SLAM in males. Crickets exhibited a progressive, age-associated decline in central zone occupancy. Juveniles spent a greater proportion of time in the central area (0.38 ± 0.35) than adults (0.22 ± 0.22; $d = 0.54$ [95% CI: 0.03, 1.06], $P = 0.03$) and geriatrics (0.12 ± 0.15; $d = 1.03$ [95% CI: 0.54, 1.52], $P < 0.0001$), with adults trending higher than geriatrics ($d = 0.55$ [95% CI: 0.08, 1.02], $P = 0.23$) (Figure 24A). When stratified by sex, both males and females exhibited the same age-dependent pattern: juvenile females (0.34 ± 0.38) spent more time centrally than geriatric females (0.13 ± 0.20; $d = 0.71$ [95% CI: 0.03, 1.40], $P = 0.03$), with no difference from adults (0.20 ± 0.18; $d = 0.46$ [95% CI: -0.27, 1.18], $P = 0.24$) (Figure 24B). Similarly, juvenile males (0.42 ± 0.33) exceeded geriatric males (0.12 ± 0.09; $d = 1.37$ [95% CI: 0.65, 2.08], $P = 0.001$), but not adults (0.23 ± 0.25; $d = 0.63$ [95% CI: -0.10, 1.36], $P = 0.10$). Neither sex exhibited differences between adult and geriatrics (d's = -0.36 to 0.64, P's = 0.33 to 0.67) nor were any sex differences observed within any age group (d's = -0.19 to 0.08, P's > 0.99) (Figure 24C).

Among geriatric crickets, only rapamycin-treated individuals (0.38 ± 0.36) trended toward increased central zone occupancy compared to geriatric controls (0.19 ± 0.14; $d = -0.67$ [95% CI: -1.32, -0.03], $P = 0.15$) (Figure 24D). When stratified by sex, this trend was evident only in males ($d = -0.80$ [95% CI: -1.71, 0.11], $P = 0.05$), while acarbose-treated females trended higher ($d = 0.99$ [95% CI: 0.03, 1.94], $P = 0.77$) (Figure 24E). Sex-stratified comparisons within treatment groups revealed no differences (d's = -0.61 to 0.82, P's = 0.25 to > 0.99) (Figure 24F).

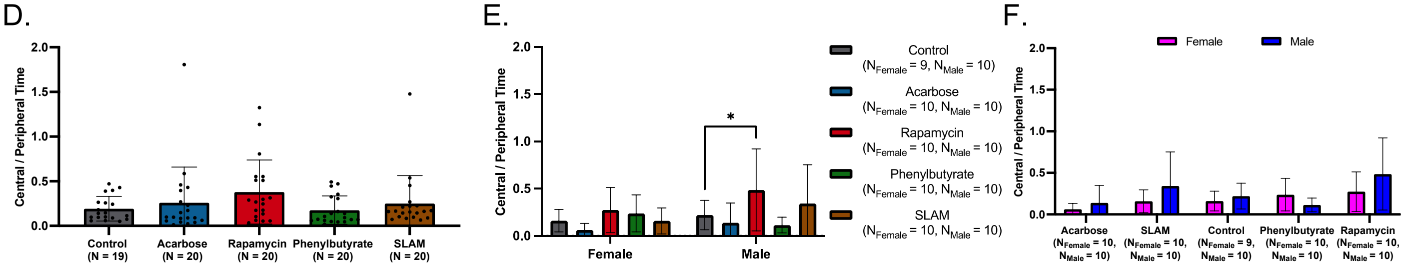
Relative to juveniles, all geriatric groups spent less time in the central zone (d's = 0.00 to 0.68, P's = 0.0018 to < 0.0001) (Figure 24G). Stratified analyses indicated that this effect was driven by males: phenylbutyrate-treated males had lower ratios than juvenile males ($d = 1.14$ [95% CI: 0.28, 2.00], $P = 0.035$), while both male and female acarbose-treated crickets trended lower (d's = -0.90 to 0.94, P's = 0.06) (Figure 24H). Compared to adults, all geriatric groups trended lower (d's = -0.55 to 0.20, P's = 0.0002 to 0.0071) (Figure 24I). When stratified by sex, rapamycin-treated males trended higher than adult males ($d = -0.76$ [95% CI: -1.58, 0.07], $P = 0.039$), while acarbose-treated females trended lower than adult females ($d = 0.92$ [95% CI: 0.08, 1.76], $P = 0.51$) (Figure 24J).

When compared to a historical geriatric cohort, rapamycin-, acarbose-, and SLAM-treated groups trended toward increased central zone time (d's = -1.10 to -0.55, P's = 0.27 to > 0.99) (Figure 24K). This effect was sex-specific: rapamycin- and SLAM-treated males spent more time centrally than historical geriatric males (*d*'s = -1.50 to -0.93, *P*'s = 0.027 to < 0.0001) and control males trended higher (*d* = -0.89 [95% CI: -1.65, -0.12], *P* = 0.62), while no differences were observed among female groups (*d*'s = -0.64 to 0.40, *P*'s = 0.31 to > 0.99) (Figure 24L).

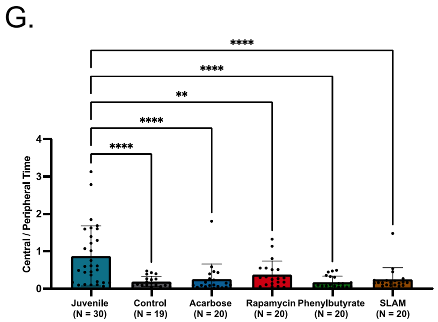
In the overall cohort, rapamycin-treated crickets trended toward spending more time in the center relative to the periphery compared to pooled controls (*d* = -0.61 [95% CI: -1.13, -0.10], *P* = 0.12), while no other treatment groups differed from controls (*d*'s = -0.12 to 0.28, *P*'s = 0.90 to > 0.99) (Figure 24M). When stratified by sex, none of the female treatment groups showed differences in central-peripheral time relative to controls (*d*'s = -0.11 to 0.49, *P*'s = 0.60 to > 0.99). Among males, rapamycin-treated individuals spent more time in the center compared to controls (*d* = -1.48 [95% CI: -2.25, -0.71], *P* = 0.0001), and males treated with the SLAM cocktail trended toward increased central time (*d* = -0.86 [95% CI: -1.59, -0.13], *P* = 0.054); other male groups did not differ from controls (*d*'s = 0.07 to 0.35, *P*'s = 0.98 to > 0.99) (Figure 24N).

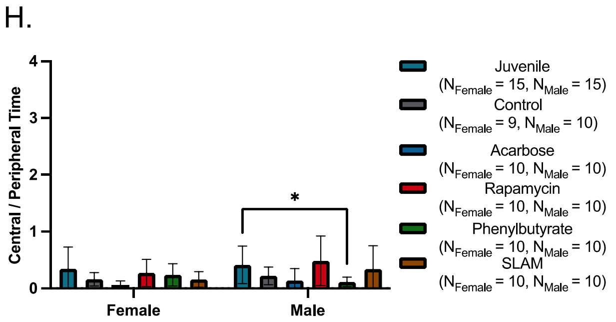


Source	SS	df	MS	F	*P*
Interaction	0.03	2	0.02	0.26	0.77
Sex	0.02	1	0.02	0.40	0.53
Group	1.19	2	0.59	9.90	0.0001
Residual	5.87	98	0.06		
Total	7.11	103			

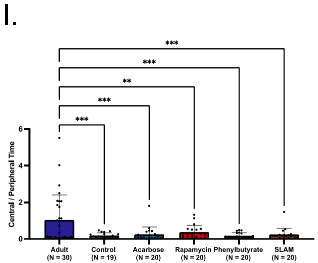


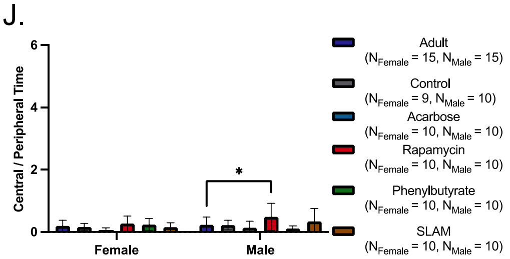
Source	SS	df	MS	F	*P*
Interaction	0.35	4	0.09	1.54	0.20
Sex	0.17	1	0.17	2.90	0.09
Group	0.87	4	0.22	3.82	0.0065
Residual	5.07	89	0.06		
Total	6.46	98			



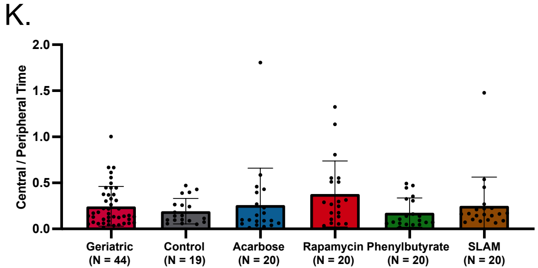


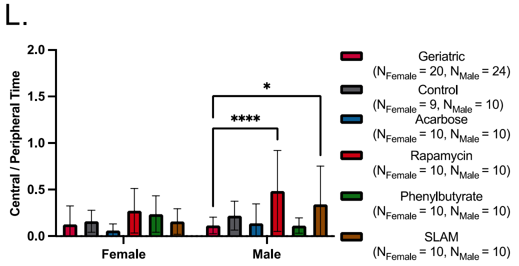
Source	SS	df	MS	F	*P*
Interaction	0.35	5	0.07	0.95	0.45
Sex	0.20	1	0.20	2.72	0.10
Group	1.46	5	0.29	3.93	0.0025
Residual	8.67	117	0.07		
Total	10.68	128			



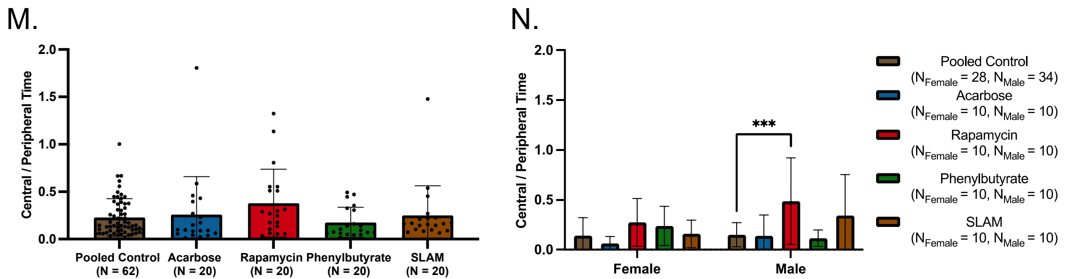


Source	SS	df	MS	F	*P*
Interaction	0.36	5	0.07	1.33	0.26
Sex	0.17	1	0.17	3.11	0.08
Group	0.87	5	0.17	3.18	0.01
Residual	6.42	117	0.05		
Total	7.82	128			





Source	SS	df	MS	F	*P*
Interaction	0.42	5	0.08	1.82	0.11
Sex	0.14	1	0.14	3.13	0.079
Group	1.16	5	0.23	5.08	0.0003
Residual	6.00	131	0.05		
Total	7.72	143			



Source	SS	df	MS	F	*P*
Interaction	0.40	4	0.10	2.16	0.077
Sex	0.15	1	0.15	3.23	0.075
Group	1.08	4	0.27	5.87	0.0002
Residual	6.09	132	0.046		
Total	7.72	141			

Figure 24. Age- and treatment-effects on time spent in the central zone. (A) Juvenile crickets exhibited higher central zone occupancy compared to adults and geriatrics. **(B)** Age-related decline in central exploration was consistent across sexes, with juveniles spending more time centrally than geriatrics in both males and females. **(C)** No sex-based differences were observed within any age cohort. **(D)** Among geriatric groups, rapamycin-treated crickets trended toward increased central zone time relative to geriatric controls. **(E)** Rapamycin-treated males spent more time centrally compared to male controls, with no treatment effects in females. **(F)** No within-treatment sex differences were observed across treatment groups. **(G)** All geriatric groups spent less time centrally than juveniles. **(H)** Phenylbutyrate- and acarbose-treated males trended lower than juvenile males, while no female groups differed from juvenile females. **(I)** Compared to adults, all geriatric treatment groups exhibited lower central zone occupancy. **(J)** Rapamycin-treated males trended higher than adult males; acarbose-treated females trended lower than adult females. **(K)** No overall group differences were detected when compared to historical geriatric controls. **(L)** Rapamycin- and SLAM-treated males spent more time centrally compared to historical geriatric males, with no differences among females. **(M)** Rapamycin treatment modestly increased central time in the overall cohort, with no changes observed under other treatments. **(N)** Male crickets treated with rapamycin or SLAM spent more time in the center compared to controls, with no differences in females (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ****$P < 0.0001$).

Treatments modulate age-related central-to-peripheral speed ratios in a sex-dependent manner. Adult crickets exhibited higher locomotor speed in the central zone relative to the periphery (3.74 ± 2.16), compared to both juvenile (2.33 ± 1.04; *d* = -0.82 [95% CI: –1.35, –0.29], *P* = 0.0013) and geriatrics (2.61 ± 1.23; *d* = 0.67 [95% CI: 0.20, 1.15], *P* = 0.006), while juvenile and geriatric cohorts did not differ (*d* = –0.24 [95% CI: –0.70, 0.22], *P* = 0.71) (Figure 25A). When stratified by sex, adult females showed elevated central-to-peripheral speed ratios (3.89 ± 2.24) compared to juvenile females (2.45 ± 1.23; *d* = -0.78 [95% CI: -1.52, -0.03], *P* = 0.03), but not to geriatric females (2.73 ± 1.21) (*d* = 0.66 [95% CI: -0.02, 1.34], *P* = 0.07) (Figure 25B). Among males, adults (3.59 ± 2.15) outpaced both juvenile (2.21 ± 0.82; *d* = -0.83 [95% CI: -1.57, -0.08], *P* = 0.04) and geriatric (2.36 ± 1.01; *d* = 0.78 [95% CI: 0.11, 1.45], *P* = 0.04) counterparts (Figure 25B). No sex differences were observed within any age cohort (*d*'s = 0.13 to 0.33, *P*'s > 0.99) (Figure 25C).

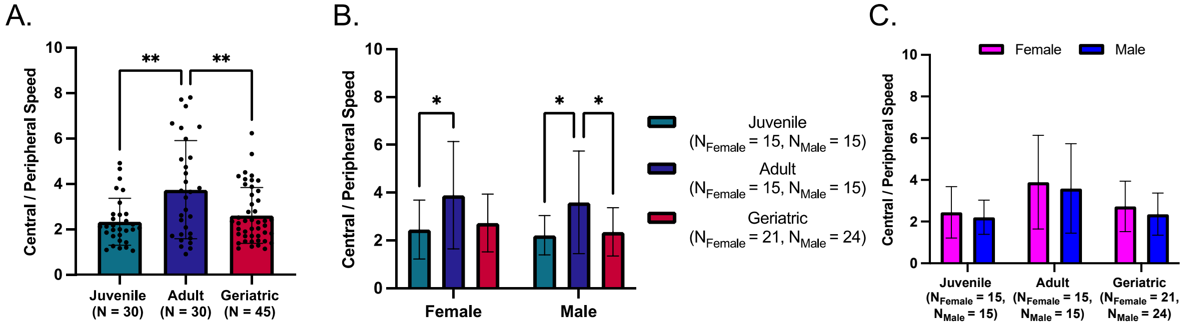
Among geriatric crickets, central zone locomotor speed was lower in rapamycin-treated (2.28 ± 0.53 cm/s; *d* = 1.06 [95% CI: 0.39, 1.73], *P* = 0.03) and SLAM-treated groups (2.27 ± 0.72 cm/s; *d* = 0.98 [95% CI: 0.31, 1.64], *P* = 0.02) compared to controls (3.13 ± 0.99 cm/s)

(Figure 25D). Acarbose (2.84 ± 1.26 cm/s) and phenylbutyrate-treated (3.30 ± 1.15 cm/s) crickets showed no such differences (*d*'s = -0.15 to 0.25, *P*'s = 0.75–0.95). When stratified by sex, females treated with rapamycin or SLAM trended toward reduced central speed relative to female controls (*d*'s = 1.17, *P*'s = 0.08 to 0.09) (Figure 25E). Among males, no treatment groups differed from control (*d*'s = -0.05 to 0.91, *P*'s = 0.26 to > 0.99) (Figure 26E). No within-group sex differences were observed across any group (*d*'s = 0.02 to 0.62, *P*'s = 0.48 to > 0.99) (Figure 25F).

Compared to juvenile crickets, central-to-peripheral speed ratios were elevated in both geriatric controls and phenylbutyrate-treated crickets (*d*'s = -0.88 to -0.77, *P*'s = 0.029 to 0.0043) (Figure 25G). Other treatment groups (acarbose, rapamycin, SLAM) showed comparable ratios to juveniles (*d*'s = -0.44 to 0.06, *P*'s = 0.28 to > 0.99). Stratification revealed that this difference was driven by females, with phenylbutyrate-treated females exhibiting higher central-to-peripheral speed ratios than juvenile females (*d* = -1.02 [95% CI: -1.87, -0.17], *P* = 0.015), while no differences were observed among males (*d*'s = -0.74 to 0.09, *P*'s = 0.28 to > 0.99) (Figure 25H). Relative to adults, rapamycin- and SLAM-treated geriatric crickets exhibited lower central-to-peripheral speed ratios (*d*'s = 0.83 to 0.84, *P*'s = 0.0014 to 0.0012) (Figure 25I). Sex-stratified analysis showed that this effect was most apparent in females from both treatment groups, which both trended higher (*d*'s = 0.80 to 0.81, *P*'s = 0.039 to 0.042), while only SLAM-treated males trended toward decreased central preference (*d* = 0.80 [95% CI: -0.03, 1.63], *P* = 0.044) (Figure 25J).

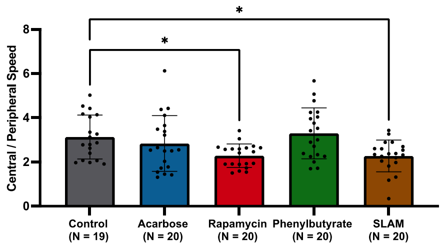
Finally, when compared to a historical geriatric cohort, phenylbutyrate-treated crickets trended toward elevated central-to-peripheral speed ratios (*d* = -0.56 [95% CI: -1.10, -0.03], *P* = 0.08) (Figure 25K). This trend was driven by females (*d* = -0.79 [95% CI: -1.57, -0.01], *P* = 0.08), while other treatment groups did not differ from historical controls (*d*'s = -0.58 to 0.30, *P*'s = 0.35 to > 0.99) (Figure 25L).

Across the overall cohort, no treatment groups differed from pooled controls in central-to-peripheral speed ratio (*d*'s = -0.46 to 0.45, *P*'s = 0.19 to > 0.99) (Figure 25M). Similarly, none of the female treatment groups showed differences from female controls (*d*'s = -0.67 to 0.44, *P*'s = 0.15 to > 0.99), and male treatment groups also remained comparable to control males (*d*'s = -0.39 to 0.38, *P*'s = 0.67 to 0.85) (Figure 25N).



Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	0.08	2	0.04	0.02	0.98
Sex	2.32	1	2.32	1.05	0.31
Group	36.07	2	18.03	8.14	0.0005
Residual	217.1	98	2.22		
Total	255.6	103			

D.



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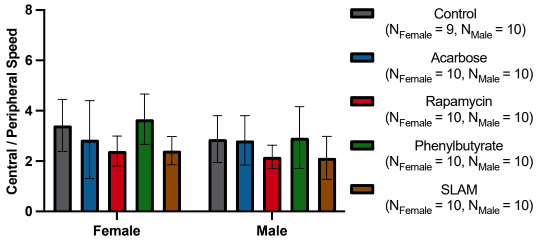

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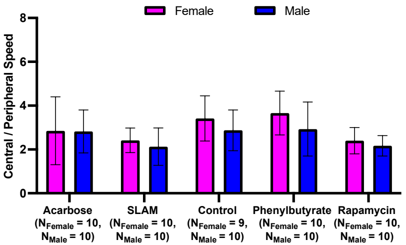
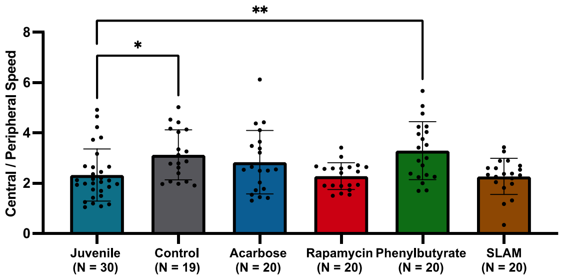


Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	1.49	4	0.37	0.40	0.81
Sex	3.28	1	3.28	3.49	0.065
Group	18.00	4	4.50	4.78	0.0015
Residual	83.76	89	0.94		
Total	106.53	98			

G.



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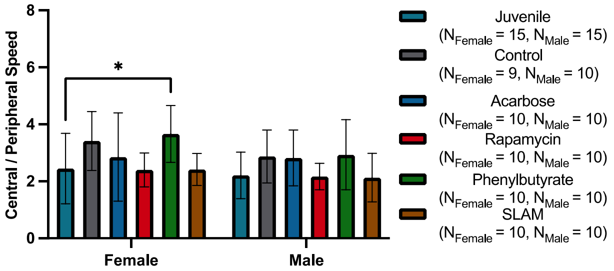

Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	1.58	5	0.32	0.32	0.90
Sex	3.71	1	3.71	3.79	0.05
Group	22.37	5	4.47	4.57	0.0008
Residual	114.4	117	0.98		
Total	142.06	128			

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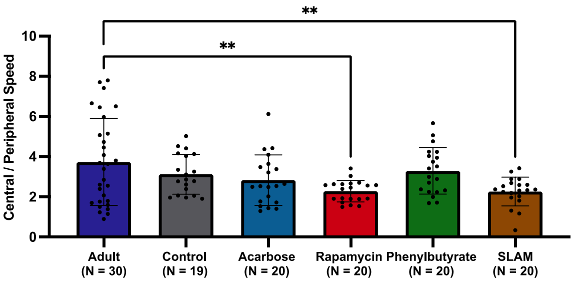

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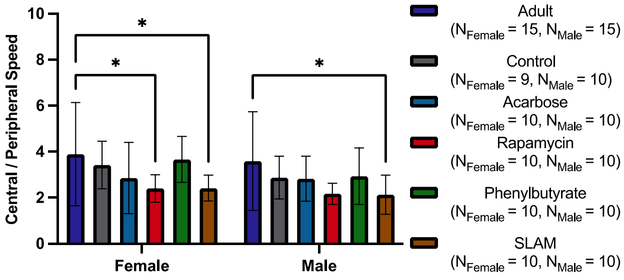
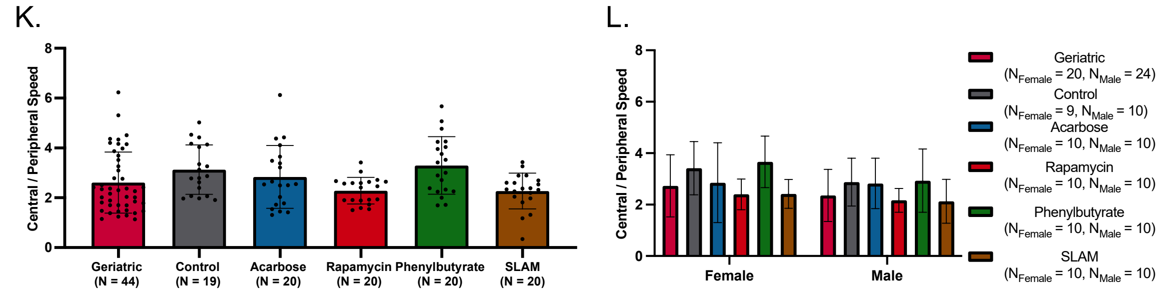
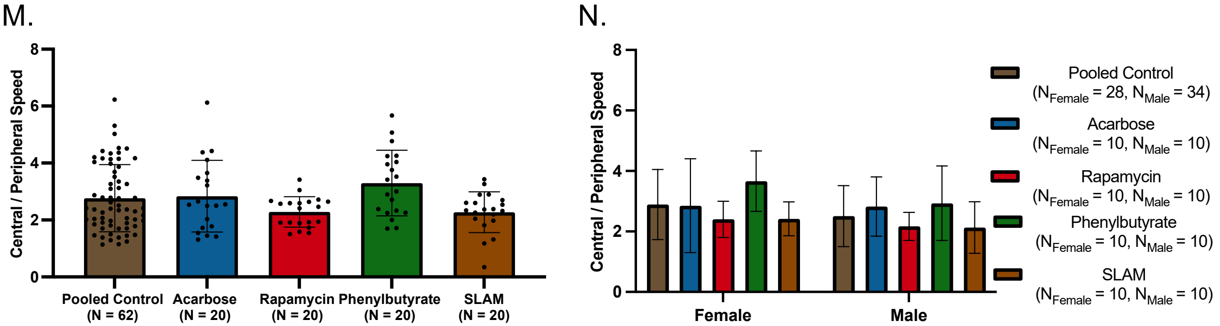


Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	1.51	5	0.30	0.16	0.98
Sex	3.94	1	3.94	2.11	0.15
Group	40.00	5	8.00	4.28	0.0013
Residual	218.8	117	1.87		
Total	264.25	128			



Source	SS	df	MS	F	*P*
Interaction	1.49	5	0.30	0.29	0.92
Sex	4.36	1	4.36	4.23	0.042
Group	19.48	5	3.90	3.78	0.0031
Residual	135.1	131	1.03		
Total	160.43	142			



Source	SS	df	MS	F	*P*
Interaction	1.33	4	0.33	0.32	0.86
Sex	3.18	1	3.18	3.05	0.083
Group	14.60	4	3.65	3.51	0.0094
Residual	137.4	132	1.04		
Total	156.5	141			

Figure 25. Age- and treatment-effects on central-to-peripheral speed (A) Adults had higher central-to-peripheral speed ratios than juvenile and geriatric cohorts. **(B)** Among males, adults had the highest ratio; among females, adults only had higher ratios than juveniles. **(C)** No sex-based differences were detected within age groups. **(D)** Rapamycin and SLAM-treated geriatrics showed reduced central zone speed compared to controls. **(E)** No treatment effects when stratified by sex. **(F)** No within-treatment sex differences. **(G)** Phenylbutyrate-treated and control geriatric groups had higher central zone speed than juveniles. **(H)** This effect was restricted to males; phenylbutyrate-treated males exhibited elevated ratios compared to juvenile males, with no differences among females. **(I)** Relative to adults, both rapamycin- and SLAM-treated crickets showed reduced central-to-peripheral speed. **(J)** These reductions were driven by females, with SLAM-treated males also showing decreased ratios. **(K)** No treatment groups differed from historical geriatric controls. **(L)** No sex-specific differences were observed relative to historical geriatric controls. **(M)** Central-to-peripheral speed ratios remained unchanged across all treatment groups in the overall cohort. **(N)** No treatment-related effects on central-peripheral speed ratio were detected in either males or females (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ****$P < 0.0001$).

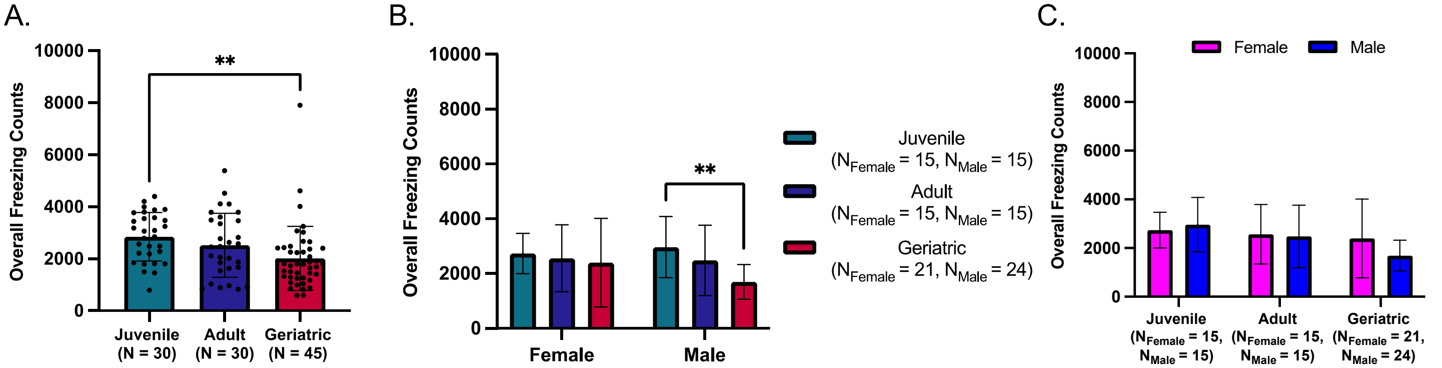
Juvenile crickets exhibit increased freezing, enhanced further by rapamycin treatment in older adults. Juvenile crickets (2846 ± 936) demonstrated a higher number of freezing episodes compared to their geriatric counterparts (2012 ± 1233; *d* = 0.73 [95% CI: 0.26, 1.21], *P* = 0.008), while adults (2518 ± 1230) did not differ from either group (juvenile vs. adult: *d* = 0.30 [95% CI: –0.21, 0.81], *P* = 0.52; adult vs. geriatric: *d* = 0.41 [95% CI: –0.06, 0.87], *P* = 0.16) (Figure 26A). Sex-stratified analyses revealed this age effect was primarily male-driven: juvenile males (2960 ± 1116) froze more frequently than geriatric males (1685 ± 633; *d* = 1.47 [95% CI: 0.75, 2.19], *P* = 0.003), while adults (2479 ± 1280) trended higher compared to geriatrics (*d* = 0.83 [95% CI: 0.16, 1.51], *P* = 0.09) (Figure 26B). In contrast, freezing behavior remained stable across age groups in females (*d*'s = 0.11-0.25, *P*'s = 0.65-0.91). No sex-based differences were observed within age groups (*d*'s = -0.24 to 0.58, *P*'s = 0.13 to > 0.99) (Figure 26C).

Among geriatric crickets, rapamycin-treated individuals (3691 ± 984) exhibited increased freezing behavior relative to untreated controls (2302 ± 755; *d* = -1.55 [95% CI: -2.26, -0.83], *P* < 0.0001). Freezing behavior also trended higher in phenylbutyrate- (2875 ± 721), SLAM- (2868 ± 841), and acarbose-treated groups (2985 ± 1239) (*d*'s = -0.76 to -0.65, *P* = 0.08 to 0.18) (Figure 26D). Rapamycin-treated females exhibited elevated freezing episodes compared to controls (*d* = -2.57 [95% CI: -3.78, -1.35], *P* = 0.0008), with phenylbutyrate- and SLAM-treated females trending higher (*d*'s = -1.08 to -0.99, *P*'s = 0.25, 0.43), while acarbose-treated females showed no difference (*d* = -0.70 [95% CI: -1.63, 0.23], *P* = 0.32) (Figure 26E). In males, rapamycin again induced increased freezing (*d* = -1.03 [95% CI: -1.96, -0.10], *P* = 0.023), whereas other treatments yielded no clear effects (*d*'s = -0.66 to -0.46, *P*'s = 0.26 to 0.70) (Figure 26E). No sex differences emerged within any treatment group (*d*'s = -0.73 to -0.04, *P*'s = 0.86 to > 0.99) (Figure 26F).

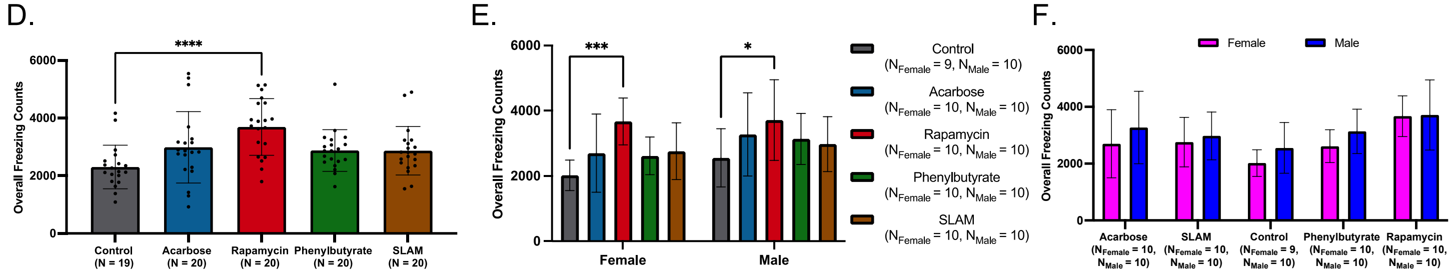
When compared to juveniles, only the rapamycin-treated group showed a clear elevation in freezing behavior (*d* = -0.87 [95% CI: -1.46, -0.28], *P* = 0.0098) (Figure 26G). This effect was largely driven by females, where a trend toward increased freezing was observed in the rapamycin group (*d* = -1.25 [95% CI: -2.12, -0.37], *P* = 0.07), while control females trended lower (*d* = 1.06 [95% CI: 0.18, 1.93], *P* = 0.27) (Figure 26H). No treatment group in males differed from juveniles (*d*'s = -0.62 to 0.38, *P*'s = 0.20 to > 0.99). Relative to adult crickets, rapamycin-treated individuals again exhibited heightened freezing (*d* = -1.01 [95% CI: -1.61, -0.41], *P* = 0.0005), a pattern consistent across sexes (*d*'s = -1.02 to -0.94, *P*'s = 0.016 to 0.0005) (Figure 26I-J).

Compared to a historical geriatric cohort, all medicated groups exhibited more freezing (*d*'s = -1.43 to -0.75, *P*'s = 0.011 to < 0.0001), while controls showed comparable freezing levels (*d* = -0.26 [95% CI: -0.79, 0.28], *P* = 0.81) (Figure 26K). This effect was replicated among males (medicated groups: *d*'s = -2.34 to -1.79, *P*'s = 0.005 to < 0.0001; control: *d* = -1.19 [95% CI: -1.98, -0.40], *P* = 0.11) (Figure 26L). In females, only rapamycin-treated individuals froze more than historical cohort (*d* = -0.89 [95% CI: -1.68, -0.11], *P* = 0.0067).

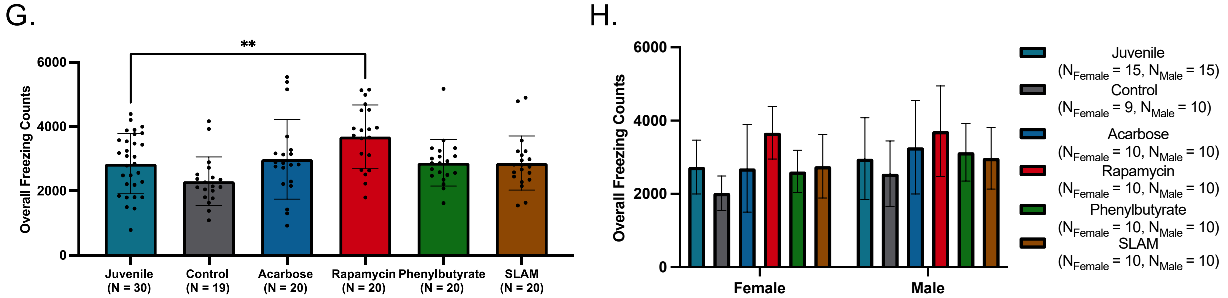
In the overall cohort, all treatment groups exhibited elevated total freezing counts compared to pooled controls (*d*'s = -1.45 to -0.72, *P*'s = < 0.0001 to 0.017) (Figure 26M). Upon sex stratification, rapamycin-treated females showed higher total freezing behavior than control females (*d* = -1.09 [95% CI: -1.85, -0.34], *P* = 0.0013), while the other female treatment groups did not differ from controls (*d*'s = -0.37 to -0.27, *P*'s = 0.58 to 0.83). Among males, all treatment groups displayed increased total freezing counts relative to control males (*d*'s = -1.89 to -1.24, *P*'s = < 0.0001 to 0.024) (Figure 26N).



Source	SS	df	MS	F	*P*
Interaction	4.23e06	2	2.11e06	1.61	0.21
Sex	8.53e05	1	8.53e05	0.65	0.42
Group	1.23e07	2	6.17e06	4.69	0.011
Residual	1.30e08	99	1.32e06		
Total	1.47e08	103			

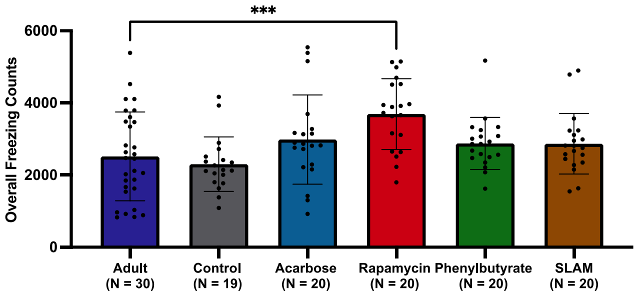


Source	SS	df	MS	F	*P*
Interaction	1.10e06	4	2.76e05	0.32	0.86
Sex	3.51e06	1	3.51e06	4.08	0.046
Group	1.96e07	4	4.89e06	5.68	0.0004
Residual	7.66e08	89	8.60e05		
Total	7.90e08	98			



Source	SS	df	MS	F	*P*
Interaction	1.23e06	5	2.45e05	0.28	0.92
Sex	3.90e06	1	3.90e06	4.50	0.04
Group	1.98e07	5	3.96e06	4.56	0.0008
Residual	1.02e08	117	8.68e05		
Total	1.27e08	128			

I.



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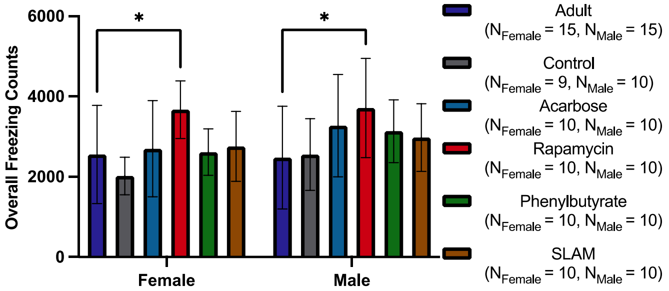
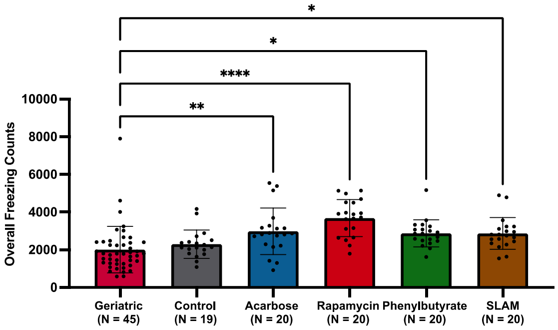


Source	SS	df	MS	F	*P*
Interaction	2.28e06	5	4.57e05	0.44	0.98
Sex	2.85e06	1	2.85e06	2.77	0.15
Group	2.38e07	5	4.76e06	4.63	0.0013
Residual	1.20e08	117	1.03e06		
Total	1.49e08	128			

K.



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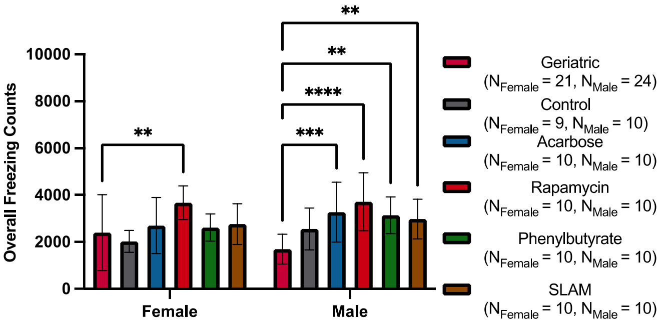
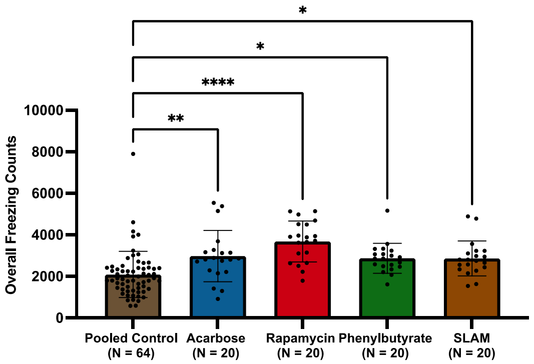


Source	SS	df	MS	F	*P*
Interaction	1.00e07	5	2.01e06	1.92	0.09
Sex	1.27e06	1	1.27e06	1.22	0.27
Group	4.52e07	5	9.05e06	8.66	<0.0001
Residual	1.38e08	132	1.04e06		
Total	1.94e08	143			

M.



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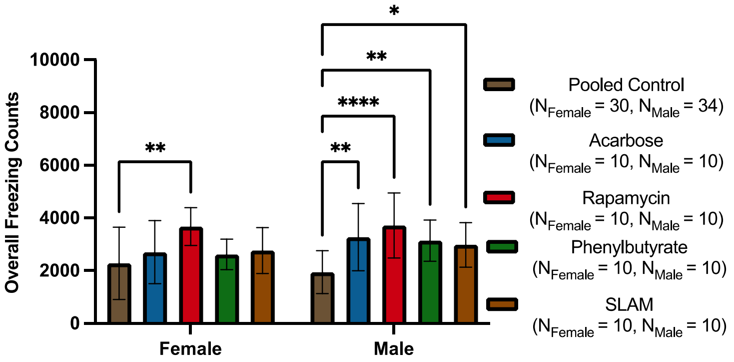


Source	SS	df	MS	F	*P*
Interaction	4.98e06	4	1.25e06	1.16	0.33
Sex	1.19e06	1	1.19e06	1.11	0.29
Group	4.45e07	4	1.11e07	10.35	<0.0001
Residual	1.44e08	134	1.08e06		
Total	1.95e08	143			

Figure 26. Age- and treatment-effects on overall freezing behavior. (A) Juveniles exhibited higher total freezing counts than geriatrics, with no difference with adults. **(B)** Male juveniles froze more than geriatrics; no age differences were observed in females. **(C)** No sex-based differences were observed within any age group. **(D)** Rapamycin-treated geriatric crickets froze more than controls. **(E)** This rapamycin-induced elevation was observed in both males and females. **(F)** No sex differences were detected within any treatment group. **(G)** Compared to juveniles, rapamycin-treated geriatric crickets exhibited more freezing. **(H)** When stratified by sex, freezing counts did not differ from juveniles in any group. **(I)** Rapamycin-treated geriatric crickets froze more than adults. **(J)** This effect was consistent in both males and females. **(K)** Compared to a historical geriatric cohort, all treatment groups except controls exhibited increased freezing. **(L)** This pattern held in males, while in females, only the rapamycin group showed an increase. **(M)** All treatments increased total freezing counts in the overall cohort, indicating enhanced behavioral suppression. **(N)** Elevated freezing was consistently observed across all treatment groups in male crickets, with a selective effect in rapamycin-treated females (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ****$P < 0.0001$).

Juvenile crickets exhibit elevated central zone freezing, which is restored in geriatric males by rapamycin. In the central zone, juvenile crickets (1177 ± 1069) froze more frequently than geriatric counterparts (386 ± 1114; $d = 0.71$ [95% CI: 0.24, 1.19], $P = 0.009$), while adults (995 ± 1160) trended higher compared to geriatric but performed similarly to juveniles ($d = 0.54$ [95% CI: 0.06, 1.00], $P = 0.06$, and $d = 0.16$ [95% CI: –0.35, 0.67], $P = 0.80$, respectively) (Figure 27A). When stratified by sex, age-related differences emerged only in males: juvenile males (1293 ± 1201) froze more than geriatric males (179 ± 133) ($d = 1.46$ [95% CI: 0.74, 2.18], $P = 0.009$), while adult males (964 ± 1278) did not differ from either group (d‘s = 0.26 to 0.97, P‘s = 0.09 to 0.70) (Figure 27B). Females showed no age-related differences in central freezing across life stages (d’s = 0.03 to 0.31, P’s = 0.48 to > 0.99), and no sex differences were observed within any age group (d‘s= –0.21 to 0.40, P’s = 0.56 to > 0.99) (Figure 27C).

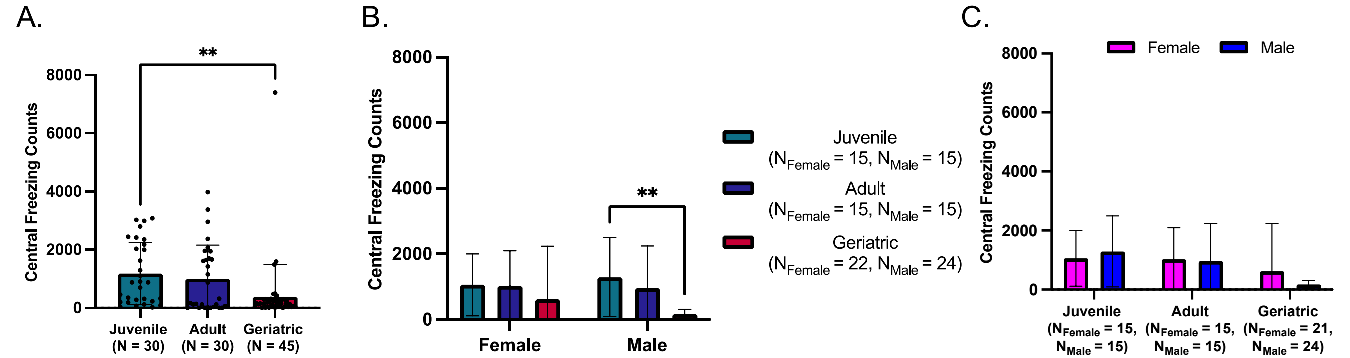
Among geriatric crickets, rapamycin treatment markedly increased central freezing (1526 ± 1109) compared to controls (412.9 ± 304.0; $d = -1.33$ [95% CI: –2.02, –0.63], $P < 0.0001$) (Figure 27D). SLAM-treated crickets (831.5 ± 658.3) trended higher than controls ($d = -0.79$ [95% CI: -1.44, -0.14], $P = 0.20$), while acarbose (401.2 ± 748.1) and phenylbutyrate (547.3 ± 412.7) showed no differences (d’s = -0.36 to 0.02, P’s = 0.94 to > 0.99). Rapamycin’s effect was observed in both sexes: rapamycin-treated males showed the largest increase ($d = -1.31$ [95% CI: -2.28, -0.35], $P = 0.0004$), followed by SLAM ($d = -1.05$ [95% CI: -1.98, -0.11], $P = 0.23$), while rapamycin-treated females also froze more in the central than controls ($d = -1.31$ [95% CI: -2.30, -0.31], $P = 0.014$) (Figure 27E). No sex differences were observed within any treatment group (d’s = -0.66 to 0.20, P’s = 0.59 to > 0.99) (Figure 27F).

Compared to juveniles, central freezing was preserved in rapamycin- and SLAM-treated geriatrics (d’s = -0.32 to 0.37, P’s = 0.46 to 0.47), but reduced in control, acarbose, and phenylbutyrate groups (d’s = 0.71 to 0.87, P’s = 0.036 to 0.0055) (Figure 27G). When stratified by sex, female crickets treated with acarbose froze less in the center than juvenile females ($d = 1.18$ [95% CI: 0.31, 2.04], $P = 0.032$), while control females trended lower ($d = 0.90$ [95% CI: 0.03, 1.76], $P = 0.16$) (Figure 27H). Relative to adults, only the acarbose and control groups trended toward reduced central freezing (d’s = 0.57 to 0.62, P’s = 0.07 to 0.08), while all other geriatric groups showed comparable levels (d’s = -0.46 to 0.47, P’s = 0.12 to 0.95) (Figure 27I). Female acarbose-treated crickets trended lower than adult females ($d = 1.00$ [95% CI: 0.15, 1.85], $P = 0.054$), while all other comparisons were nonsignificant (d’s = -0.60 to 0.76, P’s = 0.10 to > 0.99) (Figure 27J).

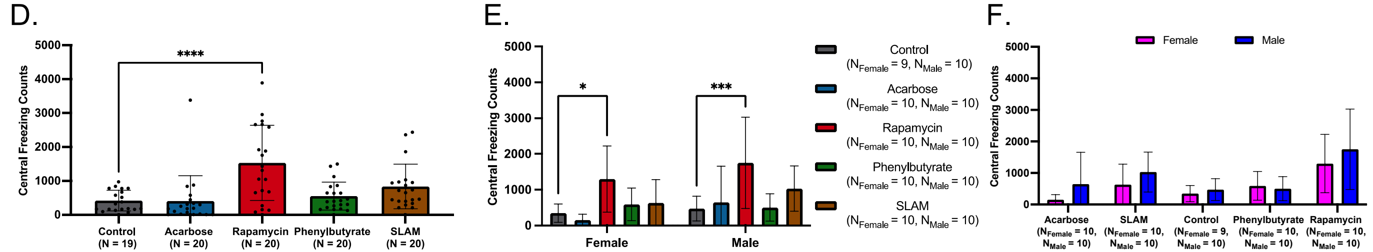
Compared to a historical geriatric cohort, only the rapamycin group exhibited elevated central freezing ($d = -1.01$ [95% CI: -1.57, 0.46], $P < 0.0001$) (Figure 27K). When stratified by sex, both the rapamycin and SLAM groups exhibited more freezing in males (d’s = -2.35 to -

2.24, *P*'s = 0.042 to < 0.0001), while control, acarbose, and phenylbutyrate groups trended higher (*d*'s = -1.37 to -0.84, *P*'s = 0.51 to 0.87) (Figure 27L). No differences from historical controls were observed in females (*d*'s = -0.46 to 0.34, *P*'s = 0.17 to > 0.99).

In the overall cohort, rapamycin-treated crickets exhibited increased freezing behavior in the central zone compared to pooled controls (*d* = -1.14 [95% CI: -1.67, -0.61], *P* < 0.0001), while no other treatment group differed (*d*'s = -0.18 to 0.32, *P*'s = 0.60 to > 0.99) (Figure 27M). When stratified by sex, none of the female treatment groups showed differences in central freezing counts compared to control females (*d*'s = -0.07 to 0.32, *P*'s = 0.60 to > 0.99). Among males, rapamycin-treated individuals exhibited elevated central freezing (*d* = -2.32 [95% CI: -3.17, -1.46], *P* < 0.0001), while the remaining male groups trended toward increased freezing as well (*d*'s = -2.04 to -0.73, *P*'s = 0.052 to 0.89) (Figure 27N).

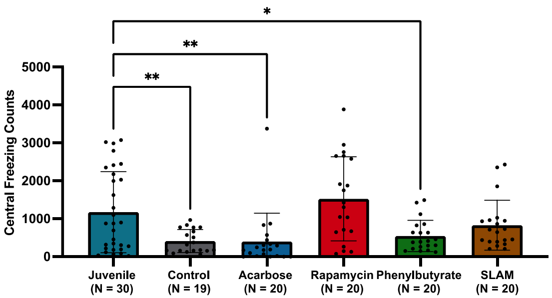


Source	SS	df	MS	F	*P*
Interaction	2.12e06	2	1.06e06	0.85	0.43
Sex	2.12e05	1	2.12e05	0.17	0.68
Group	1.25e07	2	6.26e06	5.00	0.0086
Residual	1.24e08	99	1.25e06		
Total	1.39e08	103			



Source	SS	df	MS	F	*P*
Interaction	1.24e06	4	3.11e05	0.63	0.64
Sex	1.91e06	1	1.91e06	3.86	0.053
Group	1.76e07	4	4.40e06	8.92	<0.0001
Residual	4.39e07	89	4.94e05		
Total	6.47e07	98			

G.



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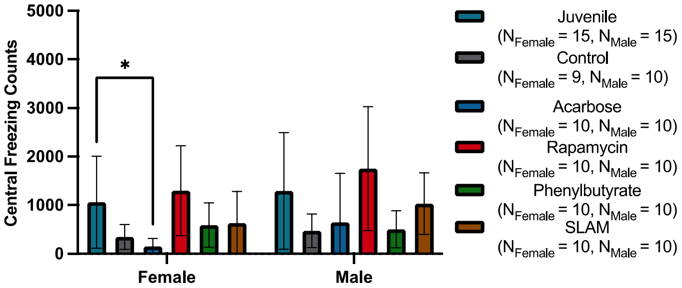
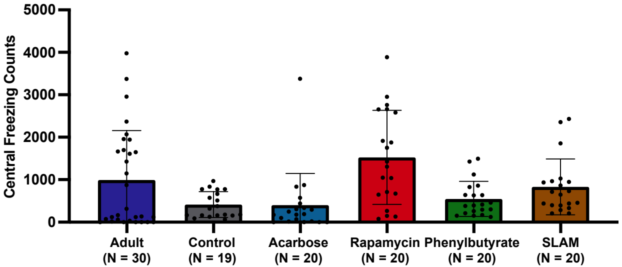


Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	1.26e06	5	2.51e05	0.38	0.86
Sex	2.30e06	1	2.30e06	3.50	0.06
Group	2.19e07	5	4.37e06	6.68	<0.0001
Residual	7.67e07	117	6.55e05		
Total	1.02e08	128			

I.



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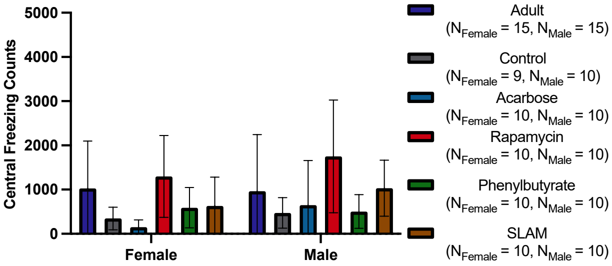
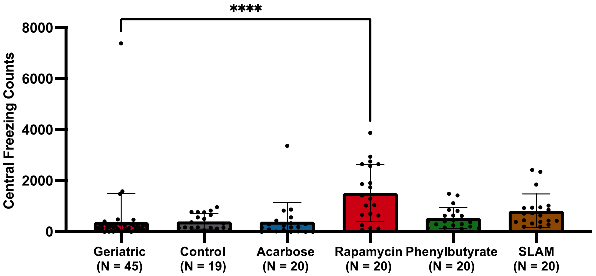


Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	1.92e06	5	3.84e05	0.54	0.74
Sex	1.54e06	1	1.54e06	2.17	0.14
Group	1.90e07	5	3.81e06	5.37	0.0002
Residual	8.29e07	117	7.09e05		
Total	1.05e08	128			

K.



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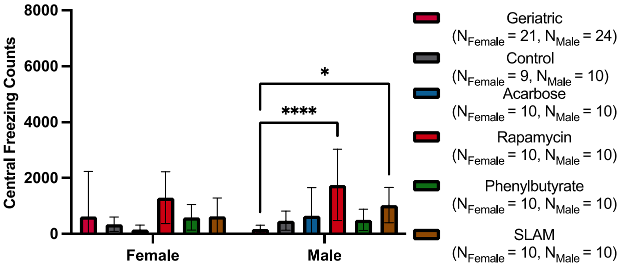
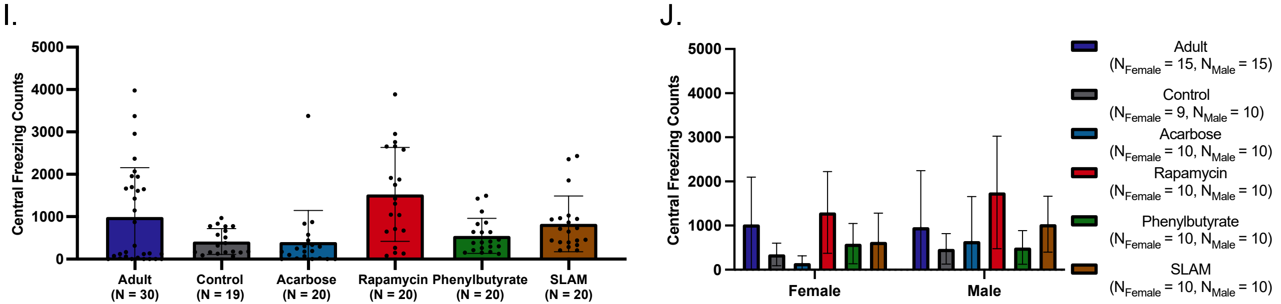
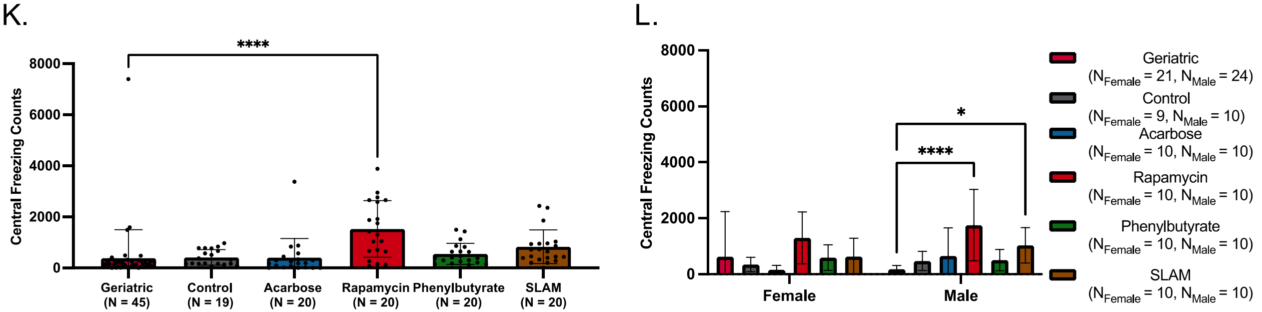


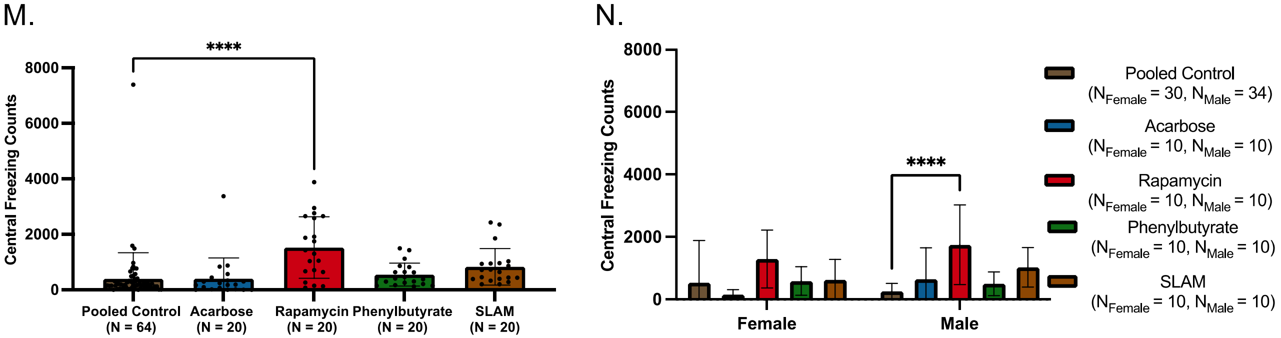
Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	5.28e06	5	1.06e06	1.48	0.21
Sex	8.10e05	1	8.10e05	1.11	0.29
Group	2.13e07	5	4.26e06	5.84	<0.0001
Residual	9.63e07	132	7.30e05		
Total	1.24e08	143			



Source	SS	df	MS	F	*P*
Interaction	1.92e06	5	3.84e05	0.54	0.74
Sex	1.54e06	1	1.54e06	2.17	0.14
Group	1.90e07	5	3.81e06	5.37	0.0002
Residual	8.29e07	117	7.09e05		
Total	1.05e08	128			



Source	SS	df	MS	F	*P*
Interaction	5.28e06	5	1.06e06	1.48	0.21
Sex	8.10e05	1	8.10e05	1.11	0.29
Group	2.13e07	5	4.26e06	5.84	<0.0001
Residual	9.63e07	132	7.30e05		
Total	1.24e08	143			



Source	SS	df	MS	F	*P*
Interaction	4.20e06	4	1.05e06	1.44	0.22
Sex	1.13e06	1	1.13e06	1.55	0.21
Group	2.13e07	4	5.33e06	7.33	<0.0001
Residual	9.74e07	134	7.27e05		
Total	1.24e08	143			

Figure 27. Age- and treatment-effects on central freezing episodes. (A) Juveniles froze more than geriatrics in the center zone; adults trended higher than geriatrics and performed

similarly to juveniles. **(B)** Juvenile males froze more than geriatric males, with no differences in females. **(C)** No sex differences within age groups. **(D)** Rapamycin-treated geriatric crickets froze more than controls; SLAM trended higher; no differences observed for acarbose and phenylbutyrate. **(E)** Rapamycin increased freezing in both sexes; SLAM trended higher in males. **(F)** No within-treatment sex differences. **(G)** Central freezing preserved in rapamycin and SLAM groups compared to juveniles. **(H)** Acarbose-treated females trended lower than adult females; control females trended lower. **(I)** Central freezing reduced in acarbose and control groups relative to adults. **(J)** Acarbose-treated females trended lower than adult females. **(K)** Rapamycin group exhibited more freezing than historical geriatrics. **(L)** Rapamycin and SLAM males froze more than historical males; no differences observed in females. **(M)** Rapamycin significantly increased central zone freezing in the overall cohort, with no changes under other treatments. **(N)** Male crickets showed strong increases in central freezing with rapamycin and milder elevations with other treatments (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ****$P < 0.0001$).

Peripheral freezing is unaffected by age; acarbose and phenylbutyrate elevate freezing in older crickets. Peripheral freezing frequency did not differ across age groups (*d*'s = -0.14 to 0.24, *P*'s = 0.69 to 0.96) (Figure 28A). Stratification by sex revealed no age-related differences in males or females (*d*'s = -0.26-0.26, *P*'s = 0.58-0.99) (Figure 28B). Within each age group, freezing behavior did not differ by sex (*d*'s = 0.01 to 0.32, *P*'s = 0.66 to > 0.99) (Figure 28C).

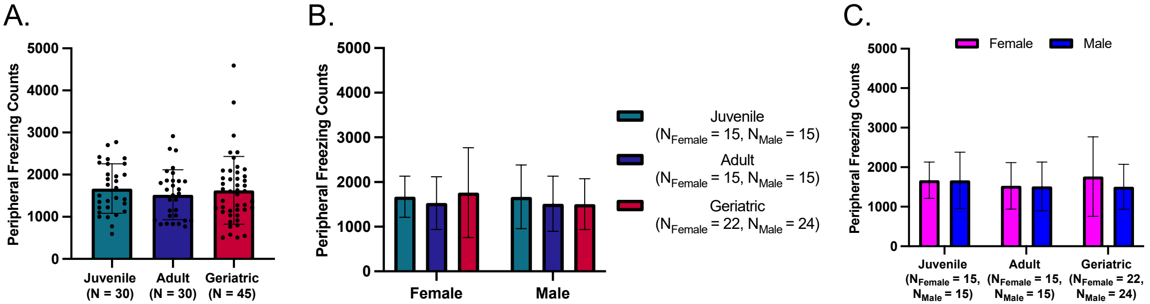
Among geriatric crickets, acarbose treatment (2584 ± 1032) increased peripheral freezing compared to untreated controls (1889 ± 722; *d* = -0.76 [95% CI: –1.41, –0.11], *P* = 0.02). Other treatments did not differ from controls (rapamycin: 2165 ± 776; phenylbutyrate: 2328 ± 754; SLAM: 2036 ± 426; *d*'s = -0.58 to -0.24, *P*'s = 0.23 to 0.93) (Figure 28D). This effect was driven by females, with acarbose-treated females exhibiting increased freezing (*d* = -0.95 [95% CI: -1.90, 0.00], *P* = 0.05) (Figure 28E). Rapamycin and SLAM groups showed trends toward elevation (*d*'s = -1.07 to -1.04, *P*'s = 0.15 to 0.50), while phenylbutyrate had no effect (*d* = -0.61 [95% CI: -1.53, 0.31], *P* = 0.70). In contrast, no differences were observed in males (*d*'s = -0.63 to 0.19, *P*'s = 0.31 to 0.99) (Figure 28E). No within-treatment sex differences were detected (*d*'s = -0.83 to 0.52, *P*'s = 0.38 to > 0.99) (Figure 28F).

Compared to juvenile controls, peripheral freezing was elevated in acarbose- and phenylbutyrate-treated groups (*d*'s = -1.13 to -0.98, *P*'s = 0.010 to 0.0001), while all other groups showed no differences (*d*'s = -0.73 to -0.34, *P*'s = 0.09 to 0.79) (Figure 28G). When stratified by sex, females treated with acarbose froze more than juvenile females (*d* = -1.07 [95% CI: -1.92, -0.22], *P* = 0.018), while those treated with rapamycin or SLAM trended higher (*d*'s = -1.16 to -1.03, *P*'s = 0.08 to 0.43) (Figure 28H). Among males, both acarbose- and phenylbutyrate-treated individuals froze more than juvenile counterparts (*d*'s = -1.26 to -1.11, *P*'s = 0.0070 to 0.0078). Relative to adult controls, freezing was increased in rapamycin-, acarbose-, and phenylbutyrate-treated groups (*d*'s = -1.31 to -0.94, *P*'s = 0.013 to < 0.0001) (Figure 28I). SLAM-treated crickets exhibited a trend toward elevated freezing (*d* = -0.95 [95% CI: -1.54, -0.35], *P* = 0.07), while untreated controls showed no difference from adults (*d* = -0.56 [95% CI: -1.14, 0.03], *P* = 0.32). Stratified analyses revealed elevated freezing in rapamycin- and acarbose-treated females (*d*'s = -1.25 to -1.17, *P*'s = 0.025 to 0.0041), and a trend in the SLAM group (*d* = -1.12 [95% CI: -1.97, -0.26], *P* = 0.18) (Figure 28J). In males, acarbose and phenylbutyrate increased freezing (*d*'s = -1.57 to -1.37, *P*'s = 0.0013 to 0.0014).

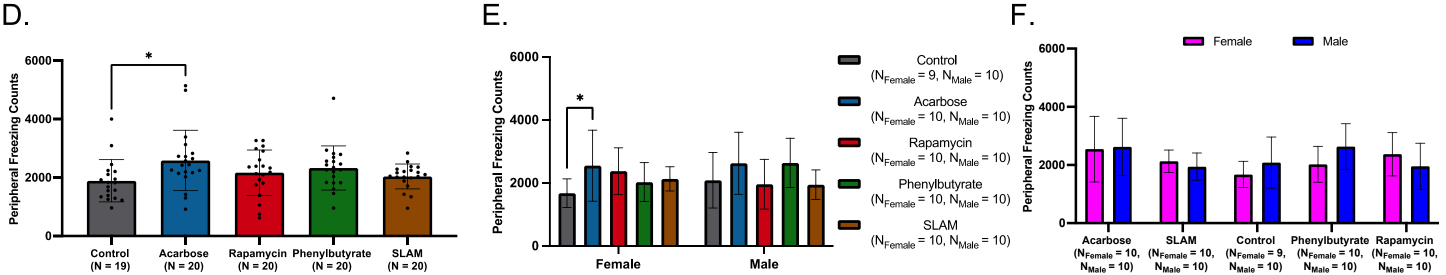
Compared to historical geriatric controls, peripheral freezing was increased in acarbose- and phenylbutyrate-treated groups (*d* = -1.08 to -0.88 [95% CI: -1.63, -0.52], *P* = 0.0050 to < 0.0001) (Figure 28K). Rapamycin and SLAM groups exhibited trends toward higher freezing (*d*'s = -0.67 to -0.57, *P*'s = 0.051 to 0.21), while untreated controls showed no difference (*d* = -0.33 [95% CI: -0.87, 0.21], *P* = 0.67). Among females, acarbose trended higher (*d* = -0.73 [95% CI: -1.50, 0.05], *P* = 0.044), while in males, both acarbose and phenylbutyrate treatments resulted in greater peripheral freezing compared to historical controls (*d*'s = -1.73 to -1.53, *P*'s = 0.0010 to

0.0009), while control and SLAM groups trended higher (*d*'s = -0.84 to -0.79, *P*'s = 0.21 to 0.48) and rapamycin showed no effect (*d* = -0.69 [95% CI: -1.45, 0.06], *P* = 0.4) (Figure 28L).

In the overall analysis, crickets treated with acarbose and phenylbutyrate exhibited greater freezing behavior in the peripheral zone compared to pooled controls (*d*'s = -1.03 to -0.80, *P*'s = < 0.0001 to 0.009), whereas the remaining treatment groups did not differ (*d*'s = -0.58 to -0.46, *P*'s = 0.084 to 0.32) (Figure 28M). When stratified by sex, acarbose-treated females showed increased peripheral freezing relative to control females (*d* = -0.85 [95% CI: -1.59, -0.11], *P* = 0.020), while rapamycin-treated females trended toward more peripheral freezing (*d* = -0.74 [95% CI: -1.47, -0.01], *P* = 0.10); other female treatment groups did not differ from controls (*d*'s = -0.49 to -0.34, *P*'s = 0.51 to 0.83). Among males, both acarbose and phenylbutyrate treatment groups displayed elevated peripheral freezing (*d*'s = -1.29 to -1.19, *P*'s = 0.003 to 0.0039), while the remaining male groups showed no differences from controls (*d*'s = -0.40 to -0.38, *P*'s = 0.76 to 0.79) (Figure 28N).

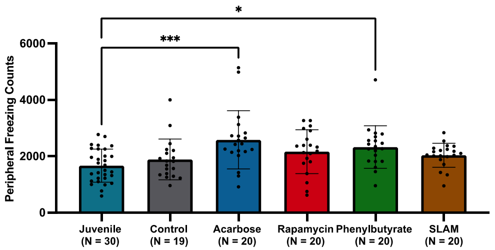


Source	SS	df	MS	F	*P*
Interaction	3.96e05	2	1.98e05	0.41	0.67
Sex	2.14e05	1	2.14e05	0.44	0.51
Group	3.61e05	2	1.80e05	0.37	0.69
Residual	4.80e07	99	4.85e05		
Total	4.81e07	103			



Source	SS	df	MS	F	*P*
Interaction	3.46e06	4	8.66e05	1.49	0.21
Sex	2.43e05	1	2.43e05	0.42	0.52
Group	5.80e06	4	1.45e06	2.50	0.048
Residual	5.16e07	89	5.80e05		
Total	6.11e07	98			

G.



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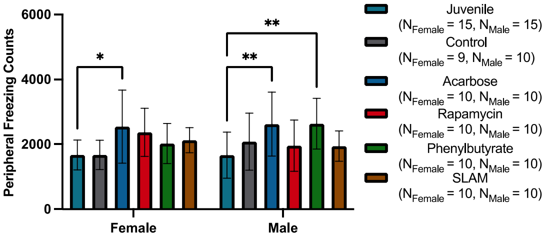
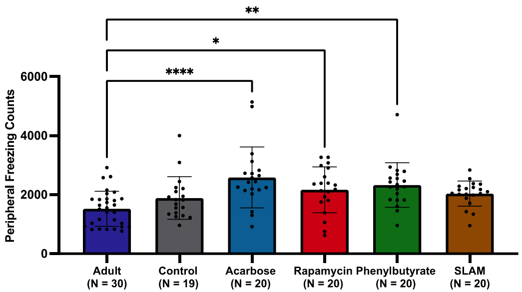
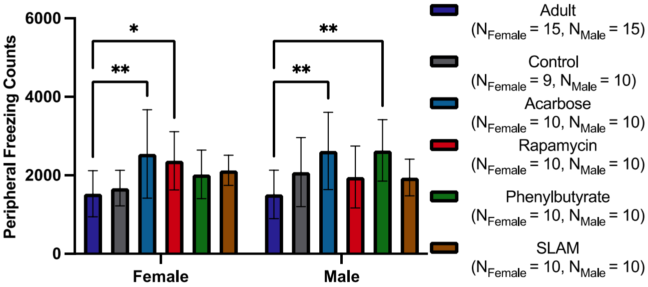


Source	SS	df	MS	F	*P*
Interaction	3.52e06	5	7.04e05	1.34	0.25
Sex	2.18e05	1	2.12e05	0.40	0.53
Group	1.23e07	5	2.46e06	4.68	0.0006
Residual	6.16e07	117	5.27e05		
Total	7.76e07	128			

I.

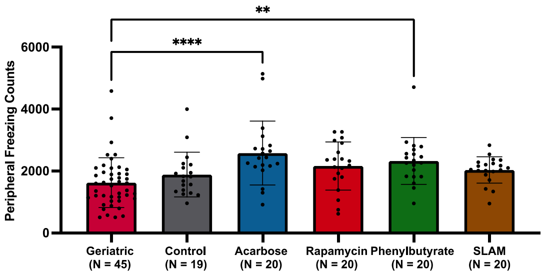


J.

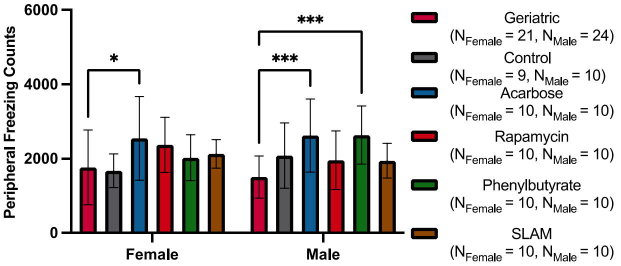


Source	SS	df	MS	F	*P*
Interaction	3.53e06	5	7.07e05	1.34	0.25
Sex	2.02e05	1	2.02e05	0.38	0.54
Group	1.64e07	5	3.28e06	6.22	<0.0001
Residual	6.18e07	117	5.28e05		
Total	8.19e07	128			

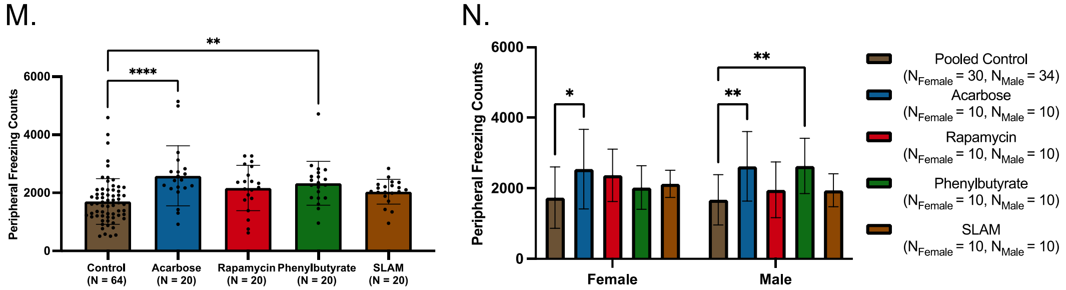
K.



L.



Source	SS	df	MS	F	*P*
Interaction	4.43e06	5	8.86e05	1.47	0.20
Sex	5.17e04	1	5.17e04	0.09	0.77
Group	1.57e07	5	3.14e06	5.23	0.0002
Residual	7.93e07	132	6.01e05		
Total	9.94e07	143			



Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	2.96e06	4	7.40e05	1.21	0.31
Sex	872.1	1	872.1	1.43e-03	0.97
Group	1.50e07	4	3.74e06	6.139	0.0001
Residual	8.17e07	134	6.10e05		
Total	9.97e07	143			

Figure 28. Age- and treatment-effects on peripheral freezing episodes. (A) Peripheral freezing frequency remained stable across juvenile, adult, and geriatric age groups. **(B)** No age-related changes observed when stratified by sex. **(C)** No sex differences detected within any age group. **(D)** Among geriatric crickets, acarbose increased peripheral freezing relative to controls. **(E)** Acarbose's effect was driven by females; males showed no differences across treatments. **(F)** No sex differences were observed within any treatment group. **(G)** Compared to juveniles, peripheral freezing was elevated in acarbose- and phenylbutyrate-treated crickets. **(H)** Female acarbose-treated crickets froze more than juvenile females; male acarbose and phenylbutyrate-treated crickets exceeded juvenile males. **(I)** Compared to adults, rapamycin, acarbose, and phenylbutyrate groups showed increased peripheral freezing; SLAM trended higher. **(J)** Female freezing was elevated in the rapamycin and acarbose groups, with a trend in SLAM; males showed increases with acarbose and phenylbutyrate. **(K)** Compared to historical geriatric controls, acarbose and phenylbutyrate elevated peripheral freezing; rapamycin and SLAM trended higher. **(L)** Among females, only acarbose trended higher; in males, both acarbose and phenylbutyrate increased freezing compared to historical controls. **(M)** Acarbose and phenylbutyrate increased peripheral freezing in the overall cohort; other treatments had no detectable effect. **(N)** Elevated peripheral freezing was observed in both acarbose- and phenylbutyrate-treated males; females showed selective or trending effects (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ****$P < 0.0001$).

A comprehensive summary of descriptive and comparative statistics is provided in Appendix 6. Table S1 details age-based group summaries for all locomotor and exploratory measures, with additional sex-stratified age group data presented in Table S2. Treatment-specific group statistics are provided in Table S3, while sex-specific treatment outcomes are delineated in Table S4. To facilitate integrated comparisons, Table S5 summarizes treatment effects across different age groups, and Table S6 extends these comparisons by incorporating sex as an additional stratification factor.

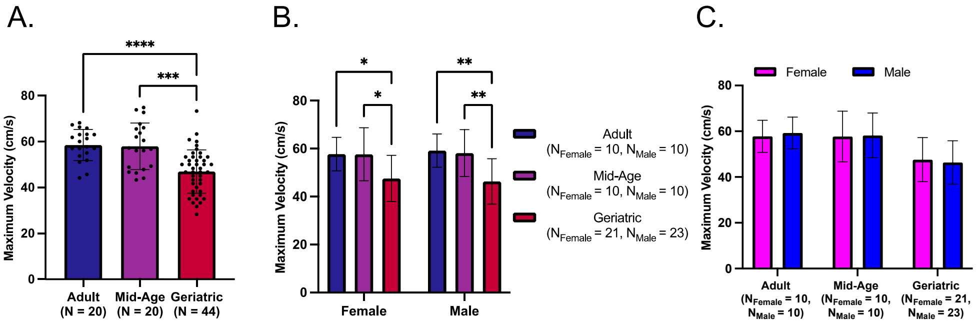
Effect sizes for locomotor and exploratory outcomes across treatment groups stratified by sex are reported in Table S7, while Table S8 presents within-group sex comparisons for each treatment cohort. Cross-group comparisons against specific age benchmarks are summarized in Tables S9–S12, which respectively report effect sizes relative to juveniles (S9), adults (S10), historical geriatric controls (S11), and pooled contemporary geriatric controls (S12). These tables collectively provide a detailed framework for evaluating the behavioral and physiological impacts of treatment across both developmental and senescent contexts.

Age-related decline in maximum velocity is rescued by rapamycin, phenylbutyrate, and SLAM treatment. Geriatric crickets (46.95 ± 9.45 cm) demonstrated reduced maximum velocity relative to both mid-age (57.94 ± 10.17 cm) and adult groups (58.50 ± 6.82 cm) (*d*'s = 1.12 to 1.31, *P*'s = 0.0009 to < 0.0001), with no differences between mid-age and adult cohorts (*d* = 0.06 [95% CI: -0.56, 0.68], *P* > 0.99) (Figure 29A). When stratified by sex, both males and females exhibited the same trend as the overall population, where geriatric crickets (male: 46.38 ± 9.45 cm; female: 47.58 ± 9.64 cm) consistently showed lower maximum velocity compared to mid-age (male: 58.18 ± 9.78 cm; female: 57.70 ± 11.08 cm) and adult groups (male: 59.22 ± 6.93 cm; female: 57.78 ± 7.00 cm) (*d*'s = 0.97 to 1.42, *P*'s = 0.015 to 0.0013) (Figure 29B). Within-group comparisons by sex did not reveal any differences among the age cohorts (*d*'s = -0.04 to 0.12, *P*'s > 0.99) (Figure 29C).

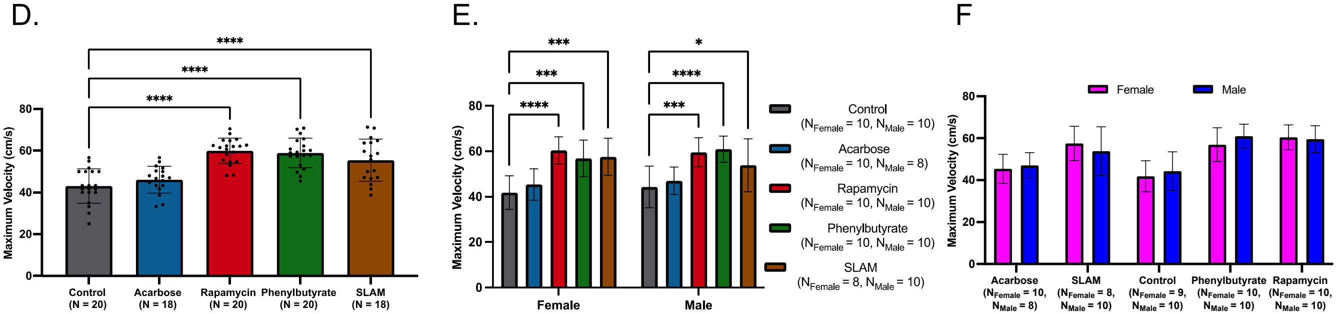
Maximum velocity data revealed that rapamycin- (59.98 ± 6.03 cm), phenylbutyrate- (58.93 ± 7.09 cm), and SLAM-treated crickets (55.45 ± 10.12 cm) exhibited higher maximum velocities compared to controls (43.08 ± 8.22 cm; *d*'s = -2.30 to -1.32, *P*'s < 0.0001), whereas acarbose-treated individuals showed no improvement (46.13 ± 6.41 cm; *d* = -0.40 [95% CI: -1.05, 0.24], *P* = 0.56) (Figure 29D). When stratified by sex, both male and female crickets independently mirrored the overall trend, demonstrating enhanced performance with rapamycin, phenylbutyrate, and SLAM treatments (*d*'s = -2.64 to -0.87, *P*'s = 0.027 to < 0.0001) (Figure 29E). Within-group sex comparisons did not reveal differences in any group (*d*'s = -0.55 to 0.35, *P*'s > 0.99) (Figure 29F).

Further comparison with age-matched adult and mid-age cohorts demonstrated that rapamycin-, phenylbutyrate-, and SLAM-treated cohorts maintained comparable maximum velocities to these younger groups (*d*'s = -0.23 to 0.39, *P*'s = 0.61 to > 0.99), while acarbose-treated and control individuals were comparably slower (*d*'s = 1.34 to 2.00, *P*'s < 0.0001) (Figures 29G, I). This consistency persisted across both male and female subgroups (*d*'s = 1.27 to 2.12, *P*'s = 0.024 to < 0.0001) (Figures 29H, J). Comparison with historical geriatric controls revealed that rapamycin-, phenylbutyrate-, and SLAM-treated individuals had increased maximum velocities (*d*'s = -1.51 to -0.87, *P*'s = 0.0017 to < 0.0001) while acarbose-treated and control individuals were comparable (*d*'s = 0.09 to 0.42, *P*'s = 0.33 to > 0.99) (Figure 29K). Stratified analyses indicated females followed the same trend as the overall population (*d*'s = -1.44 to -0.99, *P*'s = 0.024 to 0.0006), while rapamycin- and phenylbutyrate-treated males exhibited higher velocities (*d*'s = -1.67 to -1.48, *P*'s = 0.0003 to < 0.0001), with acarbose, SLAM, and control males having velocities similar to the historical geriatric group (*d*'s = -0.71 to 0.21, *P*'s = 0.094 to > 0.99) (Figure 29L).

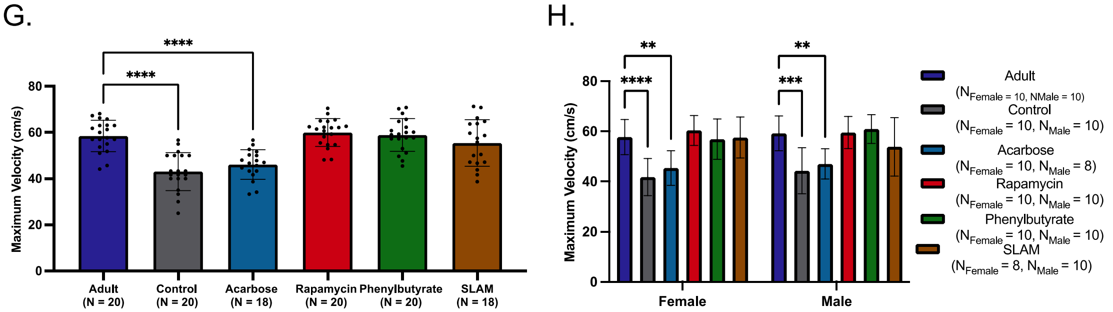
Compared to the pooled geriatric controls, rapamycin-, phenylbutyrate-, and SLAM-treated individuals achieved higher maximal velocities (*d*'s = -1.65 to -1.02, *P*'s = < 0.0001 to 0.0001), while those treated with acarbose did not differ from controls (*d* = -0.04 [95% CI: -0.57, 0.48], *P* > 0.99) (Figure 29M). When stratified by sex, both sexes followed the same pattern as the overall cohort. Among females, rapamycin-, phenylbutyrate-, and SLAM-treated individuals had elevated maximum velocities (*d*'s = -1.67 to -1.22, *P*'s = < 0.0001 to 0.0023), while acarbose-treated females did not differ from controls (*d* = 0.04 [95% CI: -0.68, 0.75], *P* > 0.99). Similarly, rapamycin-, phenylbutyrate-, and SLAM-treated males showed increased maximum velocities (*d*'s = -1.73 to -0.80, *P*'s = < 0.0001 to 0.036), while acarbose-treated males did not differ from controls (*d* = -0.14 [95% CI: -0.92, 0.63], *P* = 0.99) (Figure 29N).



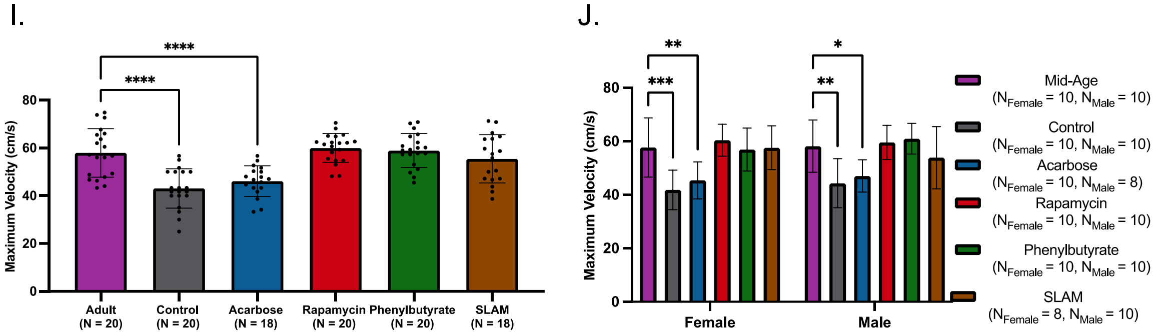
Source	SS	df	MS	F	*P*
Interaction	26.69	2	13.35	0.16	0.86
Sex	1.04	1	1.04	0.01	0.91
Group	2649	2	1324	15.51	<0.0001
Residual	6661	78	85.40		
Total	9338	83			



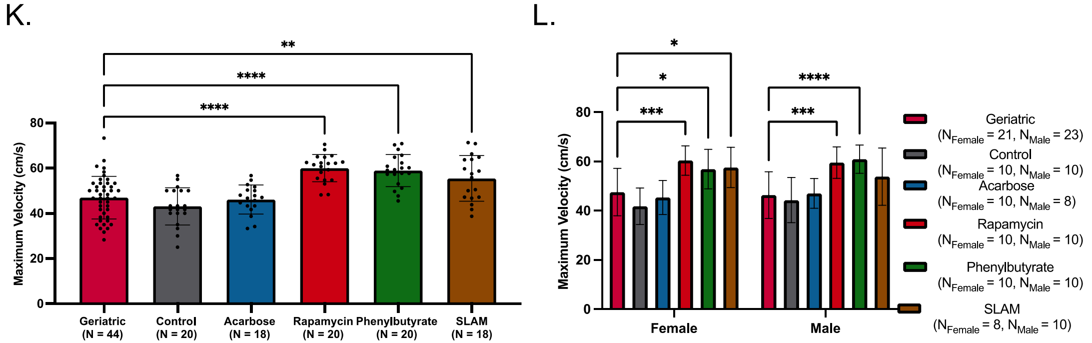
Source	SS	df	MS	F	*P*
Interaction	174.0	4	43.51	0.72	0.58
Sex	12.49	1	12.49	0.21	0.65
Group	4587	4	1147	19.04	<0.0001
Residual	5181	86	60.24		
Total	9955	95			



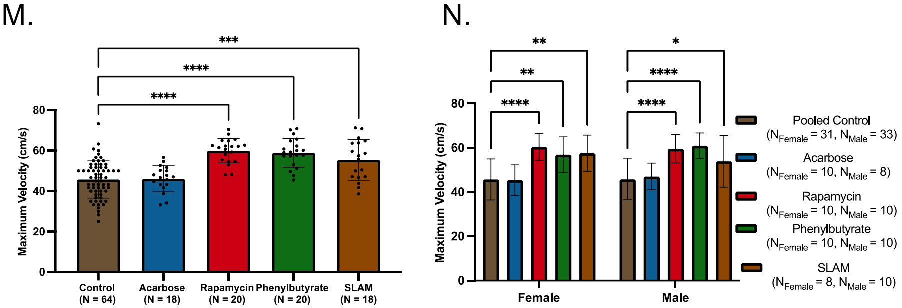
Source	SS	df	MS	F	*P*
Interaction	175.7	5	35.13	0.60	0.60
Sex	20.44	1	20.44	0.35	0.55
Group	5113	5	1023	17.56	<0.0001
Residual	6055	104	58.22		
Total	11364	115			



Source	SS	df	MS	F	*P*
Interaction	174.5	5	34.89	0.51	0.77
Sex	13.48	1	13.48	0.20	0.66
Group	5014	5	1003	14.60	<0.0001
Residual	7146	104	68.71		
Total	12348	115			



Source	SS	df	MS	F	*P*
Interaction	204.4	5	40.88	0.58	0.71
Sex	5.13	1	5.125	0.07	0.79
Group	5629	5	1126	16.00	<0.0001
Residual	9004	128	70.34		
Total	14842	139			



Source	SS	df	MS	F	*P*
Interaction	156.8	4	39.21	0.55	0.70
Sex	1.46	1	1.456	0.02	0.89
Group	5433	4	1358	19.07	<0.0001
Residual	9257	130	71.21		
Total	14848	139			

Figure 29. Maximum velocity across age and treatment groups. (A) Maximum velocity declined with age, with geriatric crickets exhibiting lower peak velocities compared to mid-age and adult cohorts. **(B)** This age-related decline was consistent across both sexes. **(C)** No sex differences were observed within each age group. **(D)** Rapamycin-, phenylbutyrate-, and SLAM-treated crickets displayed enhanced maximum velocity relative to untreated controls, while acarbose-treated individuals showed no improvement. **(E)** Sex-stratified treatment analyses reflected overall group trends. **(F)** No sex differences were detected within any treatment group. **(G–H)** Treated geriatric crickets receiving rapamycin, phenylbutyrate, or SLAM maintained maximum velocities comparable to younger cohorts, while acarbose-treated and control groups remained impaired. **(I–J)** This pattern was consistent in both males and females. **(K)** Compared to historical geriatric controls, rapamycin-, phenylbutyrate-, and SLAM-treated crickets exhibited increased peak velocities; acarbose and control groups did not differ. **(L)** Stratified analyses confirmed this trend in females, while only rapamycin- and phenylbutyrate-treated males exceeded historical controls. **(M)** Rapamycin, phenylbutyrate, and SLAM treatment enhanced maximum velocity in the overall cohort relative to pooled geriatric controls. **(N)** Sex-stratified analysis confirmed elevated maximum velocity under rapamycin, phenylbutyrate, and SLAM in both males and females (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ****$P < 0.0001$).

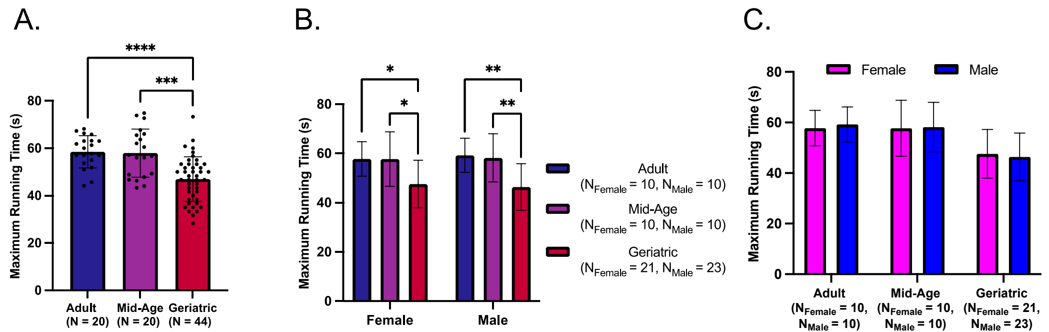
Maximum running time declines with age and is preserved by rapamycin, phenylbutyrate, and SLAM treatment. Geriatric crickets (4.73 ± 1.47s) exhibited reduced maximum running time relative to both mid-age (5.84 ± 1.78s) and adult groups (5.94 ± 1.26s) (*d*'s = 1.12 to 1.31, *P*'s = 0.0009 to < 0.0001), while no difference was observed between mid-age and adult cohorts (*d* = 0.06 [95% CI: -0.56, 0.68], *P* > 0.99) (Figure 30A). When stratified by sex, this decline persisted across both males (geriatric: 4.68 ± 1.49s; mid-age: 5.88 ± 1.61s; adult: 6.01 ± 1.24s) and females (geriatric: 4.78 ± 1.45s; mid-age: 5.79 ± 1.98s; adult: 5.88 ± 1.28s), with older individuals running for less time compared to their younger counterparts (*d*'s = 0.97 to 1.42, *P*'s = 0.015 to 0.0013) (Figure 30B). Within each age group, males and females exhibited comparable maximum running times (*d*'s = -0.04 to 0.12, *P*'s > 0.99) (Figure 30C).

Treatment restored performance in aging crickets, with rapamycin (6.10 ± 1.23s), phenylbutyrate (5.96 ± 1.28s), and SLAM (5.55 ± 1.74s) treatments increasing maximum running time relative to untreated controls (4.23 ± 1.37s; *d*'s = -2.30 to -1.32, *P*'s < 0.0001). In contrast, acarbose-treated crickets (4.52 ± 1.29s) were similar to controls (*d* = -0.40 [95% CI: -1.05, 0.24], *P* = 0.56) (Figure 30D). Sex-stratified analysis confirmed these trends in both males and females (*d*'s = -2.64 to -0.87, P's = 0.027 to < 0.0001) (Figure 30E). No sex differences were observed within any treatment group (*d*'s = -0.55 to 0.35, *P*'s > 0.99) (Figure 30F).

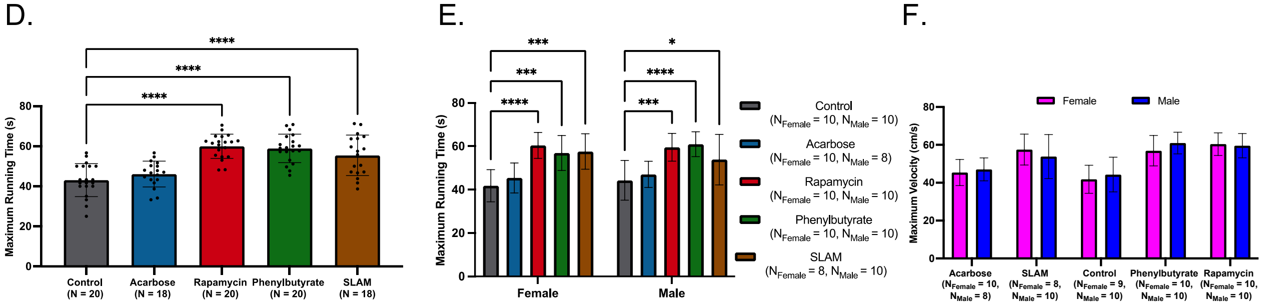
When compared to adult and mid-age cohorts, rapamycin-, phenylbutyrate-, and SLAM-treated geriatric crickets maintained youthful running performance (*d*'s = -0.23 to 0.39, *P*'s = 0.61 to > 0.99), whereas acarbose-treated and untreated controls continued to exhibit shorter running times (*d*'s = 1.34 to 2.00, *P*'s < 0.0001) (Figures 30G, I). These results held true for both males and females (*d*'s = 1.27 to 2.12, *P*'s = 0.024 to < 0.0001) (Figures 30H, J). Relative to historical geriatric controls, rapamycin-, phenylbutyrate-, and SLAM-treated crickets demonstrated improved maximum running time (*d*'s = -1.51 to -0.87, *P*'s = 0.0017 to < 0.0001), whereas acarbose-treated and untreated individuals remained unchanged (d's = 0.09 to 0.42, *P*'s = 0.33 to > 0.99) (Figure 30K). Females mirrored overall trends (*d*'s = -1.44 to -0.99, *P*'s = 0.024 to 0.0006), while among males, rapamycin- and phenylbutyrate-treated groups ran longer than historical controls (*d*'s = -1.67 to -1.48, *P*'s = 0.0003 to < 0.0001). Acarbose-, SLAM-, and control-treated males remained similar to historical levels (*d*'s = -0.71 to 0.21, *P*'s = 0.094 to > 0.99) (Figure 30L).

Overall, compared to the pooled geriatric control cohort, rapamycin-, phenylbutyrate-, and SLAM-treated individuals exhibited higher maximal running times (*d*'s = -1.65 to -1.02, *P*'s = < 0.0001 to 0.0001), whereas the acarbose group did not differ from controls (*d* = -0.04 [95% CI:

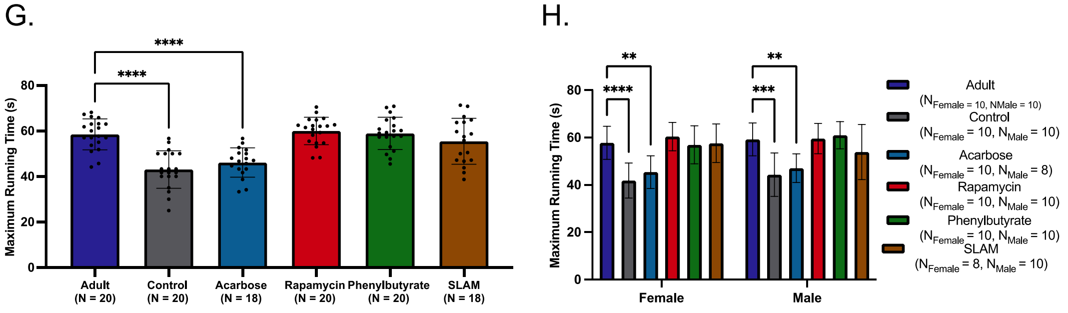
-0.57, 0.48], *P* > 0.99) (Figure 30M). When analyzed by sex, the same pattern emerged. Rapamycin-, phenylbutyrate-, and SLAM-treated females demonstrated prolonged maximum running times compared to female controls (*d*’s = -1.67 to -1.22, *P*’s = < 0.0001 to 0.0023), while acarbose-treated females remained unchanged (*d* = 0.04 [95% CI: -0.68, 0.75], *P* > 0.99). Likewise, males treated with rapamycin, phenylbutyrate, or SLAM exhibited greater running times (*d*’s = -1.73 to -0.80, *P*’s = < 0.0001 to 0.036), whereas acarbose-treated males showed no difference from controls (*d* = -0.14 [95% CI: -0.92, 0.63], *P* = 0.99) (Figure 30N).



Source	SS	df	MS	F	*P*
Interaction	26.69	2	13.35	0.16	0.86
Sex	1.04	1	1.04	0.01	0.91
Group	2649	2	1324	15.51	<0.0001
Residual	6661	78	85.40		
Total	9338	83			

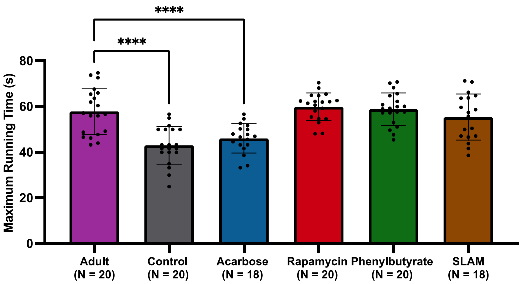


Source	SS	df	MS	F	*P*
Interaction	174.0	4	43.51	0.72	0.58
Sex	12.49	1	12.49	0.21	0.65
Group	4587	4	1147	19.04	<0.0001
Residual	5181	86	60.24		
Total	9955	95			



Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	175.7	5	35.13	0.60	0.60
Sex	20.44	1	20.44	0.35	0.55
Group	5113	5	1023	17.56	<0.0001
Residual	6055	104	58.22		
Total	11364	115			

I.



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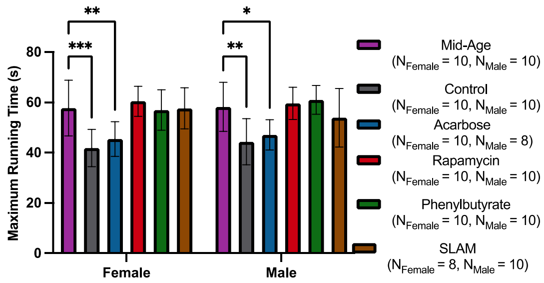
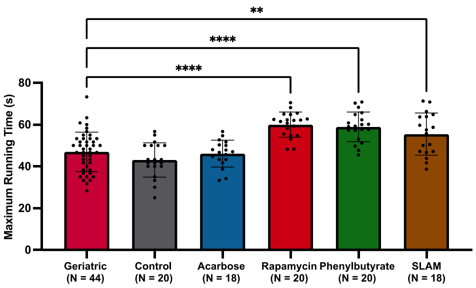


Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	174.5	5	34.89	0.51	0.77
Sex	13.48	1	13.48	0.20	0.66
Group	5014	5	1003	14.60	<0.0001
Residual	7146	104	68.71		
Total	12348	115			

K.



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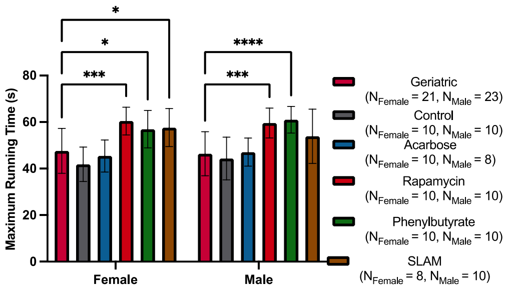
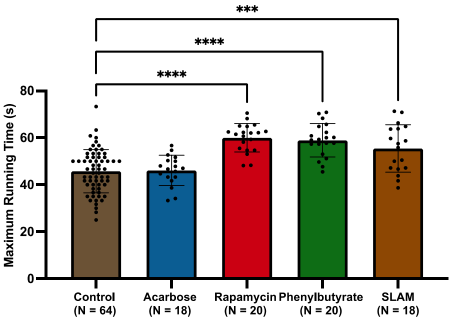


Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	204.4	5	40.88	0.58	0.71
Sex	5.13	1	5.125	0.07	0.79
Group	5629	5	1126	16.00	<0.0001
Residual	9004	128	70.34		
Total	14842	139			

M.



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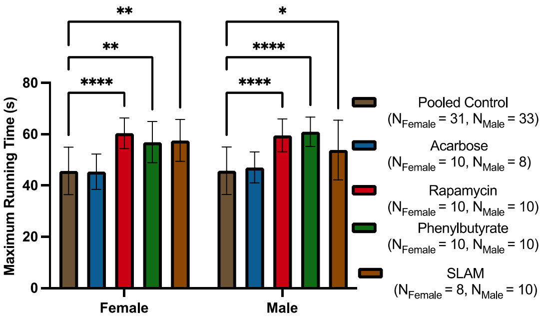


Source	SS	df	MS	F	*P*
Interaction	156.8	4	39.21	0.55	0.70
Sex	1.46	1	1.456	0.02	0.89
Group	5433	4	1358	19.07	<0.0001
Residual	9257	130	71.21		
Total	14848	139			

Figure 30. Maximum running time across age and treatment groups. (A) Geriatric crickets exhibited reduced maximum running time compared to mid-age and adult groups. **(B)** This reduction was consistent across both sexes. **(C)** Within-group sex comparisons revealed no differences in running time. **(D)** Rapamycin-, phenylbutyrate-, and SLAM-treated crickets ran for longer durations than controls, whereas acarbose-treated crickets did not differ from controls. **(E)** These treatment effects were observed in both male and female subgroups. **(F)** No sex differences emerged within any treatment group. **(G–H)** Geriatric crickets treated with rapamycin, phenylbutyrate, or SLAM showed running durations comparable to mid-age and adult cohorts; acarbose-treated and control crickets did not. **(I–J)** These effects persisted across both sexes. **(K)** Relative to historical geriatric controls, maximum running time was higher in crickets treated with rapamycin, phenylbutyrate, or SLAM, but unchanged in those receiving acarbose or no treatment. **(L)** This trend was confirmed in females; among males, only rapamycin and phenylbutyrate improved performance. **(M)** Maximal running duration was increased by rapamycin, phenylbutyrate, and SLAM treatment in the overall cohort. **(N)** Both sexes showed enhanced running time under rapamycin, phenylbutyrate, and SLAM; acarbose had no effect (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ****$P < 0.0001$).

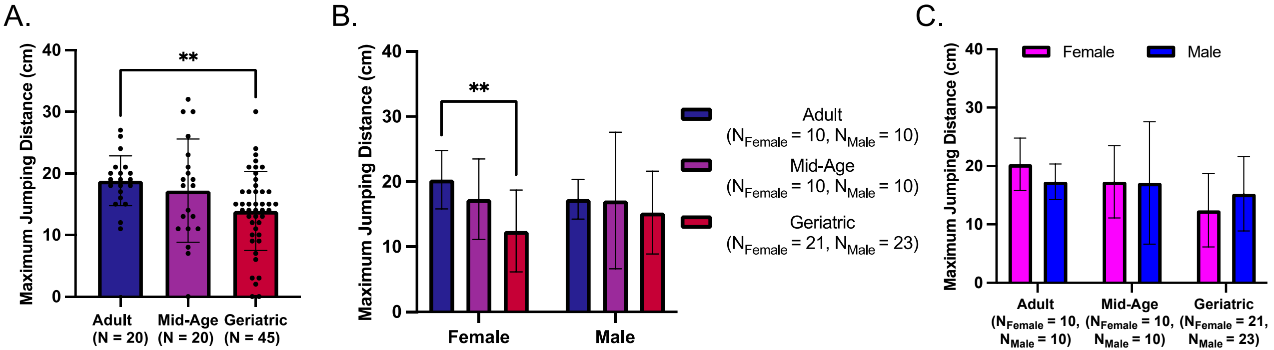
Maximum jumping distance is preserved in aging crickets via a sex-specific manner by rapamycin and acarbose treatment. Maximum jumping distance declined with age in the overall population, with geriatric crickets (13.91 ± 6.42 cm) showing reduced performance relative to adults (18.80 ± 4.03 cm) (*d* = 0.83 [95% CI: 0.29, 1.38], *P* = 0.0081), though no difference was detected between geriatric and mid-age groups (17.20 ± 8.38 cm; *d* = 0.35 [95% CI: -0.19, 0.88], *P* = 0.38) (Figure 31A). Stratified analyses revealed a sex-specific pattern (Figure 31B). Female crickets mirrored the overall trend, with geriatric females (12.43 ± 6.28 cm) jumping shorter distances than adults (20.30 ± 4.47 cm; *d* = 1.33 [95% CI: 0.50, 2.15], *P* = 0.0063), but not mid-age females (17.30 ± 6.18 cm; *d* = 0.76 [95% CI: -0.02, 1.54], *P* = 0.13). In contrast, male crickets did not exhibit age-related differences in jumping distance (*d*'s = 0.02 to 0.35, *P*'s = 0.69 to > 0.99). Within-group sex comparisons across all age cohorts revealed no differences (*d*'s = -0.44 to 0.75, *P*'s = 0.46 to > 0.99) (Figure 31C).

None of the drug treatments improved maximum jumping distance in geriatric crickets relative to controls (18.10 ± 8.02 cm), with all groups performing comparably (acarbose: 21.39 ± 6.62; rapamycin: 21.30 ± 6.41; phenylbutyrate: 17.00 ± 8.72; SLAM: 17.83 ± 8.34; *d*'s = -0.43 to 0.13, *P*'s = 0.49 to > 0.99) (Figure 31D). This pattern persisted when stratified by sex, with no differences among treated and control crickets in either males or females (*d*'s = -0.75 to 0.45, *P*'s = 0.27 to > 0.99) (Figure 31E), nor within-group sex differences across any treatment cohort (*d*'s = -0.59 to 0.49, *P*'s = 0.67 to > 0.99) (Figure 31F).

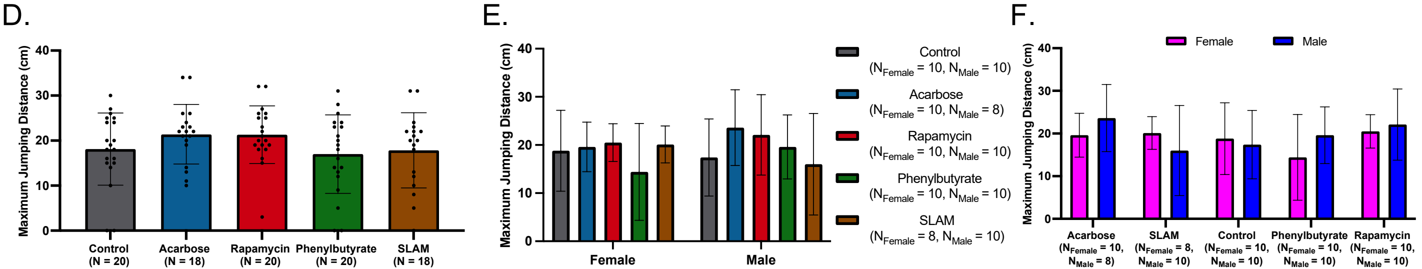
When comparing treatment groups to younger cohorts, no differences in jumping distance were observed between treated geriatric crickets and mid-age or adult controls (*d*'s = -0.54 to 0.26, *P*'s = 0.33 to > 0.99) (Figures 31G, I). This pattern held across both females (*d*'s = -0.59 to 0.73, *P*'s = 0.24 to > 0.99) and mid-age males (*d*'s = -0.66 to 0.10, *P*'s = 0.28 to > 0.99) (Figure 31H, J). However, acarbose-treated males trended higher than adult males (*d* = -1.06 [95% CI: -2.05, -0.07], *P* = 0.23).

Compared to a historical geriatric cohort, acarbose- and rapamycin-treated individuals exhibited higher maximum jumping distances (*d*'s = -1.44, *P*'s = 0.0.0018 to 0.0013), with controls trending higher (*d* = -0.59 [95% CI: -1.13, -0.05], *P* = 0.15) (Figure 31K). Stratified analyses revealed that rapamycin-treated females (*d* = -1.39 [95% CI: -2.22, -0.56], *P* = 0.021) and acarbose-treated males (*d* = -1.21 [95% CI: -2.06, -0.35], *P* = 0.027) outperformed their historical controls (Figure 31L). Rapamycin-treated males also trended higher (*d* = -0.95 [95% CI: -1.73, -0.18], *P* = 0.065), while acarbose, SLAM, and control females showed moderate increases (*d*'s = -1.30 to -0.89, *P*'s = 0.052 to 0.11).

Overall, compared to the pooled geriatric control cohort, acarbose- and rapamycin-treated individuals achieved higher maximal jumping distances (*d*'s = -0.87 to -0.86, *P*'s = 0.0085 to 0.0065), while phenylbutyrate- and SLAM-treated individuals did not differ (*d*'s = -0.35 to -0.23, *P*'s = 0.54 to 0.80) (Figure 31M). When stratified by sex, only rapamycin-treated females trended toward greater jumping distance (*d* = -0.86 [95% CI: -1.60, -0.12], *P* = 0.098), while the remaining female groups did not differ from controls (*d*'s = -0.79 to 0.01, *P*'s = 0.20 to > 0.99). Among males, acarbose-treated individuals exhibited greater jumping distances (*d* = -1.07 [95% CI: -1.88, -0.27], *P* = 0.034), rapamycin-treated males trended higher (*d* = -0.84 [95% CI: -1.57, -0.11], *P* = 0.080), and the remaining male groups showed no differences from controls (*d*'s = -0.53 to -0.01, *P*'s = 0.50 to > 0.99) (Figure 31N).

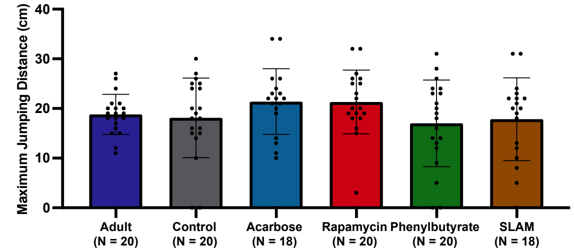


Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	122.4	2	61.20	1.46	0.24
Sex	0.28	1	0.28	0.01	0.94
Group	387.0	2	193.5	4.60	0.013
Residual	3279	78	42.04		
Total	3789	83			



Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	275.9	4	68.98	1.17	0.33
Sex	26.75	1	26.75	0.45	0.50
Group	335.7	4	83.91	1.42	0.23
Residual	5067	86	58.92		
Total	5705	95			

G.



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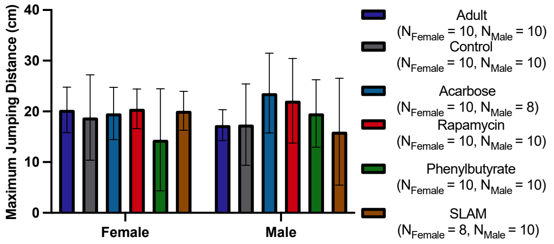

Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	345.8	5	69.16	1.35	0.25
Sex	4.23	1	4.23	0.08	0.77
Group	338.1	5	69.16	1.32	0.26
Residual	5332	104	51.26		
Total	6020	115			

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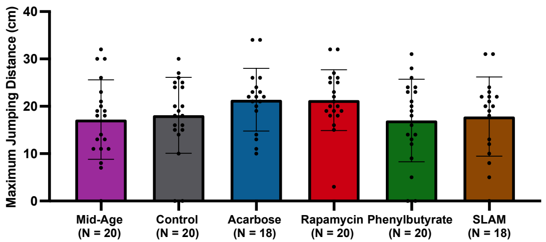

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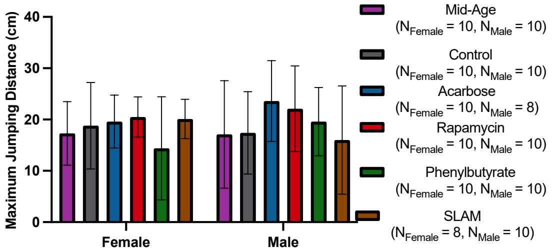
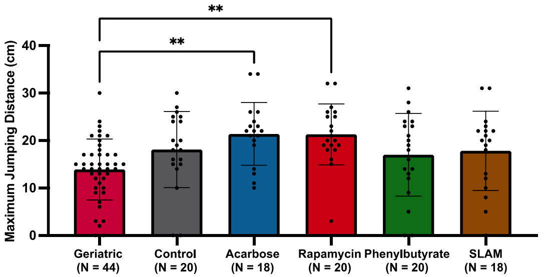


Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	283.0	5	56.60	0.92	0.47
Sex	20.81	1	20.81	0.34	0.56
Group	400.9	5	80.18	1.30	0.27
Residual	6400	104	61.54		
Total	7105	115			

K.



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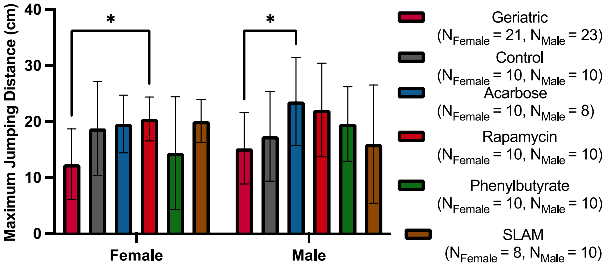
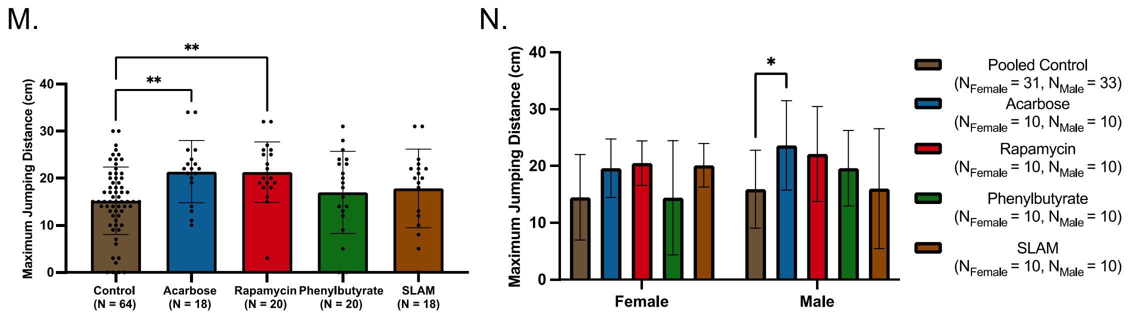


Source	**SS**	**df**	**MS**	**F**	***P***
Interaction	298.2	5	59.64	1.13	0.35
Sex	57.96	1	57.96	1.10	0.30
Group	1194	5	238.8	4.53	0.0008
Residual	6749	128	52.73		
Total	8299	139			



Source	SS	df	MS	F	*P*
Interaction	237.1	4	59.27	1.09	0.36
Sex	72.34	1	72.34	1.33	0.25
Group	939.3	4	234.8	4.33	0.0026
Residual	7056	130	54.28		
Total	8305	139			

Figure 31. Age- and treatment-effects on maximum jumping distance. (A) Geriatric crickets displayed reduced maximum jumping distances compared to adults, but not mid-age crickets. **(B)** Female crickets exhibited age-related decline in jumping performance, with shorter distances in geriatric females relative to adults. **(C)** No sex differences were observed within age groups. **(D)** Maximum jumping distance did not differ among treatment groups compared to untreated geriatric controls. **(E)** Treatment effects remained absent when stratified by sex. **(F)** No within-group sex differences were observed across treatment cohorts. **(G-J)** When compared to adult and mid-age cohorts, treatment groups did not differ in maximum jumping distance overall or by sex, except for a trend toward increased jumping distance in acarbose-treated males. **(K)** Compared to a historical geriatric cohort, rapamycin- and acarbose-treated crickets showed greater jumping distances, with controls trending higher. **(L)** Stratified comparisons revealed that rapamycin-treated females and acarbose-treated males exhibited the greatest improvements relative to historical controls. **(M)** Acarbose and rapamycin treatments improved jumping performance in the overall cohort; other treatments had no effect. **(N)** Acarbose enhanced jumping in males; rapamycin showed a sex-dependent trend toward improvement (**P* < 0.05, ***P* < 0.01, ****P* < 0.001).

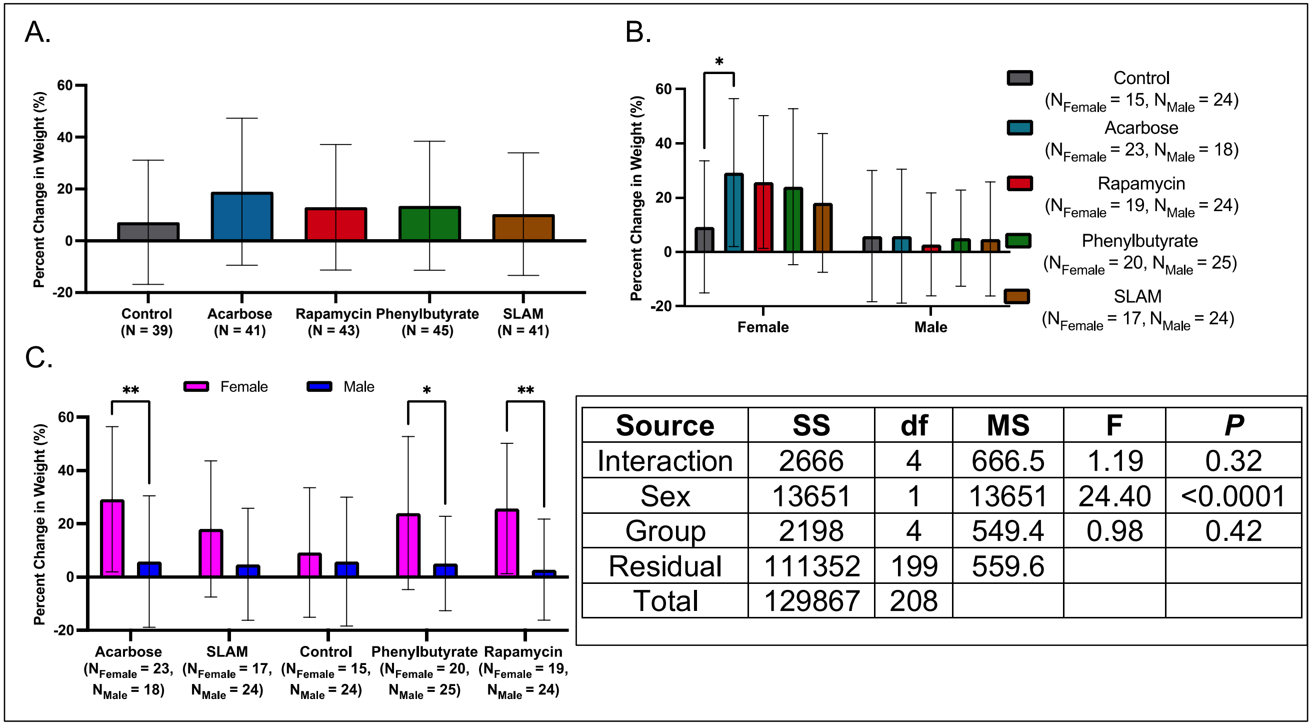
A comprehensive summary of descriptive and comparative statistics is provided in Appendix 7. Table S1 details age-based group summaries, with additional sex-stratified age group data presented in Table S2. Treatment-specific group statistics are provided in Table S3, with corresponding effect sizes reported in Table S4. Sex-stratified treatment data and effect sizes are presented in Table S5-S7. Cross-group comparisons against specific age benchmarks are summarized in Tables S8–S10, which respectively report effect sizes relative to adults (S8), historical geriatric controls (S9), and pooled contemporary geriatric controls (S10). These tables collectively provide a detailed framework for evaluating the behavioral and physiological impacts of treatment across both developmental and senescent contexts.

Intermittent treatment of acarbose, rapamycin, and phenylbutyrate increased percent weight gain in females. Due to the inability to reliably track individual crickets prior to behavioral testing, stemming from limited morphological distinguishability in group-housed conditions, individualized body weight was recorded only at the conclusion of the study following experimental separation. To estimate treatment-related changes in somatic maintenance in the absence of longitudinal within-subject data, percent weight change was calculated for each individual as a function of the difference between its final weight and the average baseline weight of its respective treatment group and cohort:

$$Percent\ Change = \frac{Initial\ Group\ Average - Final\ Individual\ Weight}{Final\ Individual\ Weight}\ x\ 100$$

To account for potential batch effects, crickets were divided into two independently tested cohorts.

Across all treatment groups, percent weight change was used to evaluate somatic maintenance. No overall differences were observed between treated and control groups (*d*'s = 0.13 to 0.44, *P*'s = 0.11 to 0.94) (Figure 32A), nor were there differences within sex-stratified comparisons (*d*'s = -0.14 to 0.75, *P*'s = 0.13 to >0.99) (Figure 32B), with the exception of acarbose-treated females, who exhibited substantially greater weight gain compared to control females (29.21 ± 27.26% vs. 9.25 ± 24.33%, *d* = 0.75 [95% CI: 0.07, 1.42], *P* = 0.039). Within-group comparisons revealed consistently greater weight gain in females relative to males in the acarbose-, rapamycin-, and phenylbutyrate-treated groups (*d*'s = -1.05 to -0.80, *P*'s = 0.0089 to 0.042) (Figure 32C).



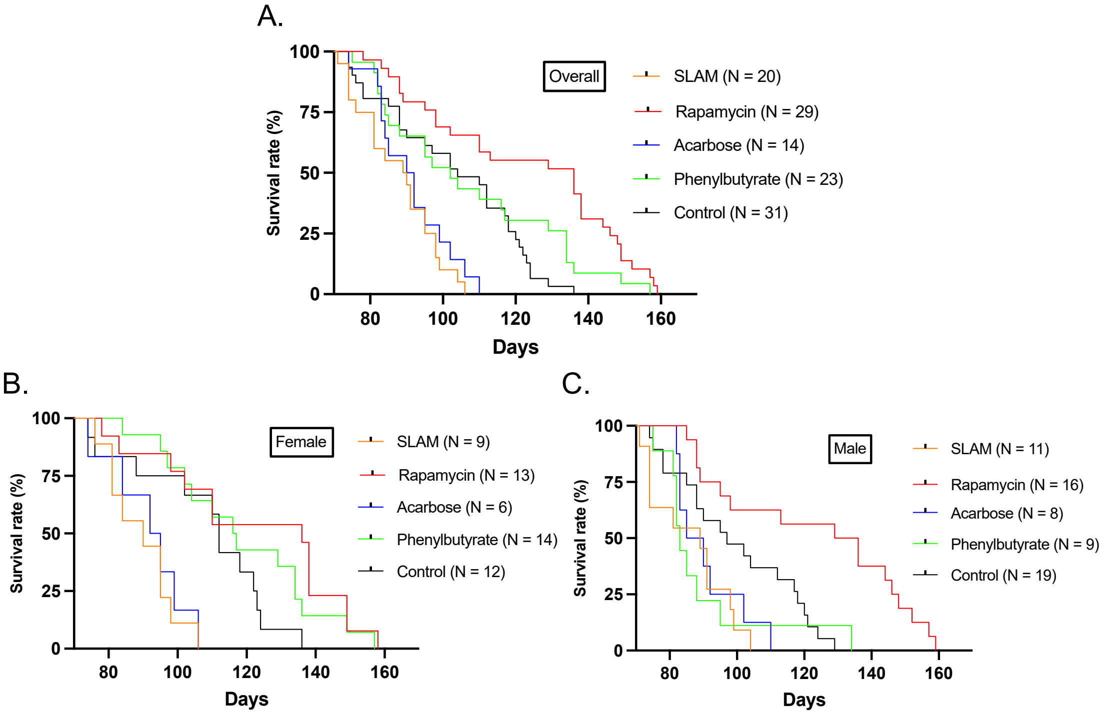
Source	SS	df	MS	F	*P*
Interaction	2666	4	666.5	1.19	0.32
Sex	13651	1	13651	24.40	<0.0001
Group	2198	4	549.4	0.98	0.42
Residual	111352	199	559.6		
Total	129867	208			

Figure 32. Percent Weight Change Following Treatment Across Groups and Sexes. (A) Overall percent weight change did not differ between control and treatment groups. **(B)** When stratified by sex, all treatment groups remained comparable to same-sex controls, except for greater percent weight change in acarbose-treated females. **(C)** Within-group sex comparisons revealed that females in the acarbose, rapamycin, and phenylbutyrate groups experienced greater percent weight changes than their male counterparts (**P* < 0.05, ***P* < 0.01).

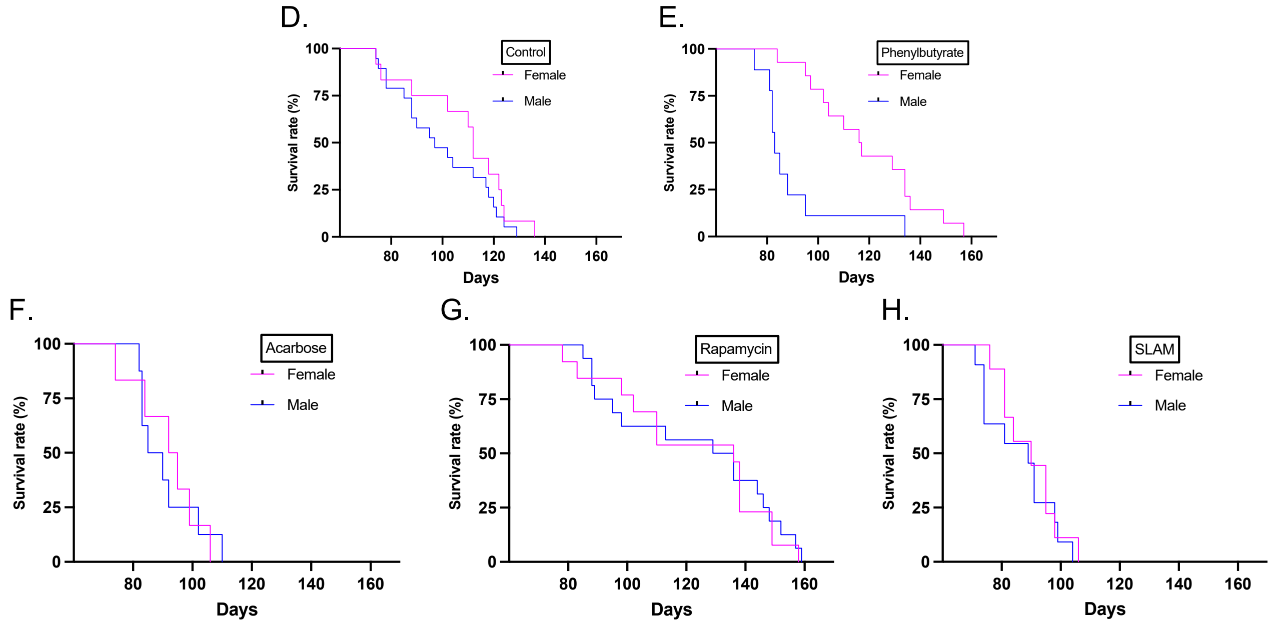
Detailed summary statistics can be found in Appendix 8. Table S1 presents age-related group summaries and those stratified by sex.

Intermittent rapamycin extends post-treatment lifespan, while acarbose and SLAM reduced longevity in a sex-dependent manner. To assess whether intermittent drug exposure conferred lasting survival benefits beyond the period of behavioral testing, subsections of crickets from each treatment group were monitored for lifespan following the cessation of drug administration and resumed *ad libitum* access to standard chow and water. Overall, rapamycin-treated individuals exhibited a marked extension in post-treatment lifespan compared to controls (median: 136 vs. 104 days, *HR*: 0.42 [95% CI: 0.25, 0.73], *P* = 0.0004) (Figure 33A). In contrast, intermittent treatment with acarbose (91 days) or SLAM cocktail (89.5 days) was associated with shortened lifespan relative to controls (*HR*'s = 2.30 to 2.51, *P*'s = 0.0008 to 0.015). Phenylbutyrate-treated individuals showed no survival advantage (99.5 days, *HR*: 0.72 [95% CI: 0.42, 1.24], *P* = 0.80).

Sex-stratified analyses revealed that rapamycin-treated males retained a robust survival advantage (132.5 vs. 97 days, *HR*: 0.40 [95% CI: 0.20, 0.81], *P* = 0.0064) (Figure 33C), while females treated with either acarbose (93.5 days) or SLAM (90.0 days) continued to show reduced survival compared to female controls (*HR*'s = 2.92 to 3.03, *P*'s = 0.014 to 0.04) (Figure 33B). Within-sex comparisons indicated no major sex-based differences in post-treatment lifespan across most treatment groups (*HR*'s = 0.93, 1.51, *P*'s = 0.92 to >0.99) (Figures 33D, F-H), with the exception of phenylbutyrate-treated females, who outlived their male counterparts (116.5 vs. 83 days, *HR*: 3.22 [95% CI: 1.08, 9.65], *P* = 0.0068) (Figure 33E).



Group	Overall			Female			Male		
	Survival (days)	*HR* (95% CI)	Adj. *P*-value	Survival (days)	*HR* (95% CI)	Adj. *P*-value	Survival (days)	HR (95% CI)	Adj. *P*-value
Control[1]	104.0	Reference		112.0	Reference		97.0	Reference	
PBA	99.5	0.72 (0.42, 1.24)	0.80	116.5	0.62 (0.28, 1.39)	0.76	83.0	1.35 (0.58, 3.14)	>0.99
ACB	91.0	2.30 (1.05, 5.07)	**0.015**	93.5	3.03 (0.81, 11.4)	**0.04**	87.5	1.94 (0.73, 5.21)	0.34
RAP	136	0.42 (0.25, 0.73)	**0.0004**	136.0	0.48 (0.20, 1.12)	0.13	132.5	0.40 (0.20, 0.81)	**0.0064**
SLAM	89.5	2.51 (1.27, 4.95)	**0.0008**	90.0	2.92 (1.01, 8.44)	**0.014**	89.0	2.19 (0.91, 5.29)	0.084



	Control		Phenylbutyrate		Acarbose		Rapamycin		SLAM	
	Male	Female[1]	Male	Female[1]	Male	Female[1]	Male	Female[1]	Male	Female[1]
Survival (days)	97.0	112.0	83.0	116.5	87.5	93.5	132.5	136.0	89.0	90.0
HR (95% CI)	1.51 (0.75, 3.04)		3.22 (1.08, 9.65)		1.05 (0.37, 3.02)		0.93 (0.45, 1.94)		1.26 (0.52, 3.02)	
Adj. *P* -value	0.92		**0.0068**		>0.99		>0.99		>0.99	

[1]Reference groups for effect size estimations and statistical testing.

Figure 33. Post-treatment lifespan following intermittent drug exposure. (A) Rapamycin-treated individuals exhibited increased lifespan while acarbose- and SLAM-treated groups showed decreased survival relative to controls. **(B)** Acarbose- and SLAM-treated females exhibited reduced lifespan. **(C)** Rapamycin-treated males demonstrated extended survival compared to controls. **(D)** Sex comparison within control group showing no difference in lifespan. **(E)** Phenylbutyrate-treated females outlived their male counterparts. **(F–H)** Sex comparisons within the acarbose, rapamycin, and SLAM groups revealed no sex-specific differences in post-treatment lifespan.

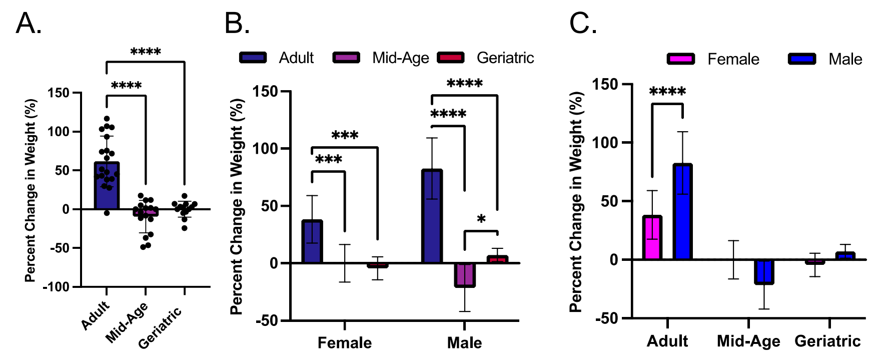
Several individuals were excluded from escape paradigm analyses due to mortality occurring before or during learning and retention phases. Mortality occurred at various stages of the experiment, leading to the exclusion of affected individuals from subsequent analyses, including retention tests. Prior to final weight measurement, one adult female, one mid-aged female, three geriatric males, and three mid-aged males died.

During the learning paradigm, one mid-aged male failed the first two days of testing and was found deceased in its cage prior to the third day. Consequently, this individual was excluded from all subsequent analyses, including retention tests. Similarly, one geriatric male and one geriatric female failed the first day of testing, and were found deceased before the second day, leading to their exclusion from further analysis.

For the retention tests, one adult female successfully completed the learning paradigm and the 1-day retention, but died before the 1-week retention test, necessitating exclusion from long-term memory analyses. Additionally, one mid-aged female, despite passing the learning paradigm, died before completing either retention test. Among mid-aged males, five successfully completed the learning paradigm and 1-day retention test, but died prior to the 1-week retention test, while one individual died before completing either retention assessment.

These exclusions were accounted for in all statistical analyses to ensure data integrity and accurate interpretation of experimental outcomes.

Age-related decline in physiological resilience is observed through percent weight gain. Adult crickets (61.72 ± 32.63%) exhibited greater percent changes in weight compared to both mid-aged (-9.45 ± 20.81) and geriatric cohorts (0.06 ± 10.23) (*d*'s = 2.30 to 2.49, *P*'s < 0.0001), but not between mid-age and geriatrics (*d* = -0.55 [95% CI: -1.29, 0.20], *P* = 0.56) (Figure 34A). When stratified by sex, females mirrored the overall population trend, with adults (38.38 ± 20.74%) displaying greater percent changes in weight than both mid-aged (-0.001 ± 16.35%) and geriatric groups (-4.45 ± 9.97%) (*d*'s = 1.96 to 2.45, *P*'s = 0.0003 to 0.0001). Among males, the same trend was observed (adults: 82.74 ± 26.67%; mid-age: -21.59 ± 20.52; geriatric: 7.26 ± 5.90; *d*'s = 3.17 to 4.06, *P*'s < 0.0001), but an additional distinction emerged: mid-aged males exhibited lower percent changes in weight than their geriatric counterparts (*d* = -1.63 [95% CI: -2.95 to -0.31], *P* = 0.035) (Figure 34B). Within-group sex comparisons revealed that adult females exhibited lower percent changes in weight than adult males (*d* = -1.76 [95% CI: -2.82, -0.70], *P* < 0.0001), while mid-aged females trended higher than males (*d* = 1.12 [95% CI: 0.06, -2.18], *P* = 0.091), and geriatric females trended lower than males (*d* = -1.25 [95% CI: -2.47, -0.03], *P* = 0.87) (Figure 34C).



Source	SS	df	MS	F	p
Age	50289	2	25145	68.83	<0.0001
Sex	1505	1	1505	4.12	0.049
Interaction	9367	2	4684	12.82	<0.0001
Residual	15342	42	365.3		
Total	97503	47			

Figure 34. Age- and sex-differences in percent change in weight. (A) Adult crickets had higher weight changes than their mid-age and adult counterparts. **(B)** Both sexes generally followed the same trend as the overall population. **(C)** Adult males had higher weight changes than females (age groups = 13-19/cohort, ****P* < 0.001, *****P* < 0.0001).

Learning performance decreases with age. Across five cumulative testing days, geriatric crickets exhibited reduced task success rates compared to their mid-age and adult counterparts, reflecting a marked decline in cognitive performance with age (Figure 35A). For the first 3 days, fewer geriatric crickets (6.25-42.86%) successfully completed the task compared to adults (45.00-100.00%; *RR*'s = 2.28 to 7.20, *P*'s = 0.04 to 0.0004), but not to mid-age groups (36.84-83.33%; *RR* = 1.62 to 5.89, *P*'s = 0.05 to 0.59). By the fourth and fifth day, both mid-age (88.89-100.00%) and adult crickets (100.00%) maintained a higher success rate than geriatrics (50.00-57.14%; *RR*'s = 1.70 to 2.00, *P*'s = 0.04 to 0.001).

Sex-stratified analyses revealed distinct patterns (Figure 35B-C). Among females, no differences in success rates were observed between geriatric (12.50-71.43%) and mid-age females (40.00-100.00%) throughout the entire five days (*RR*'s = 1.17 to 3.20, *P*'s = 0.31 to > 0.99). For adult females, they did not have higher success rates than geriatrics during the first two days (50.00-90.00%; *RR*'s = 2.10 to 4.00, *P*'s = 0.202 to 0.304), although demonstrated higher success rates by day three (100.00%; *RR* = 2.22 [95% CI: 0.93, 5.28], *P* = 0.029), although this difference diminished over the subsequent days (100.00%; *RR*'s = 1.33 to 1.67, *P*'s = 0.10 to 0.31). In contrast, males exhibited more pronounced age-related differences: while no differences emerged on day one (*RR*'s = 5.67 to 6.80, *P*'s = 0.18 to 0.41), both adult (90.00%) and mid-age males (66.67%) outperformed geriatric males by day two (0.00%; *RR*'s = 10.0 to 13.5, *P*'s = 0.022 to 0.0008). By days three, four, and five, adult males (100.00%) consistently demonstrated higher success rates than geriatric males (28.57-42.86%; *RR*'s = 2.22 to 3.33, *P*'s = 0.029 to 0.0068), while mid-age males (87.50-100.00%) no longer exhibited an advantage over geriatrics (*RR*'s = 2.20 to 3.06, *P*'s = 0.05 to 0.08). Within group sex comparisons across all age cohorts revealed no sex differences (*RR*'s = 1.00 to 1.67, *P*'s = 0.59 to > 0.99) (Figure 35D). Detailed tables are presented in Appendix 8.

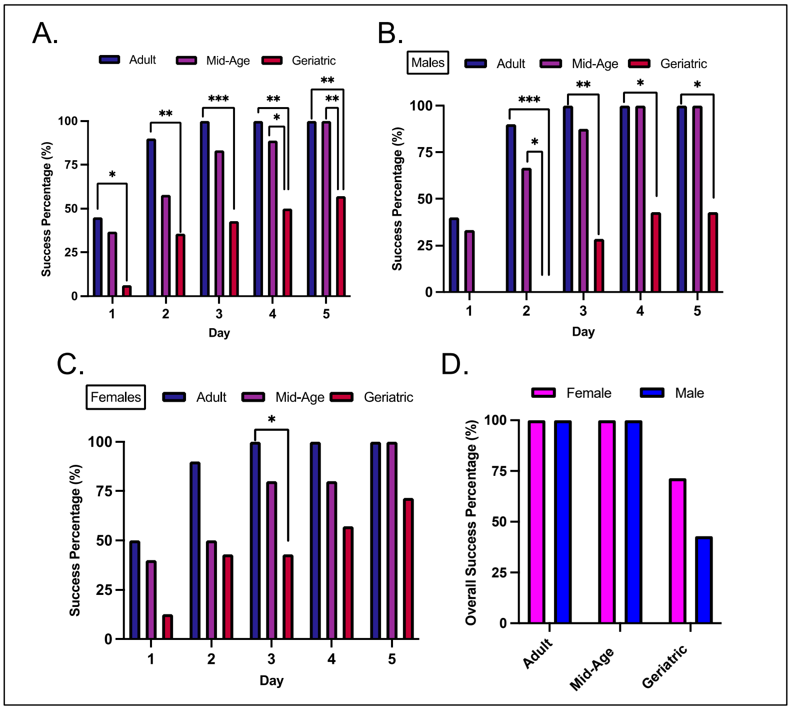


Figure 35. Age- and sex-differences in success percentages. (A) Geriatric crickets performed worse on learning tasks than their mid-age and adult counterparts. **(B)** Geriatric males followed similar trends as the overall population, while **(C)** differences among female cohorts were less pronounced. **(D)** No within-group sex differences emerged (age groups = 16-20/cohort, **P* < 0.05, ***P* < 0.01, ****P* < 0.001).

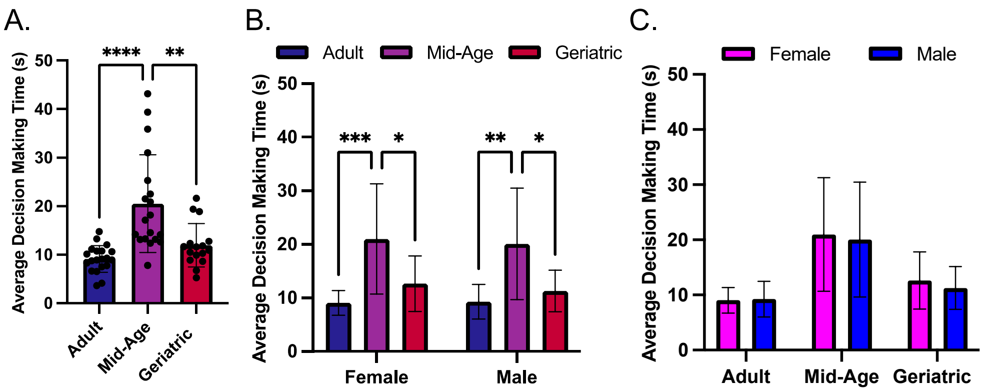
Decision-making was most delayed in mid-age crickets across both training and test trials. During main learning trials, mid-age crickets displayed the longest average decision-making times (20.54 ± 10.07s), exceeding both adults (9.15 ± 2.75s) and geriatric (11.96 ± 4.45s) counterparts. Pairwise comparisons confirmed robust group differences between adult and mid-age (*d* = -1.53 [95% CI: -2.24, -0.82], *P* < 0.0001), as well as between mid-age and geriatric crickets (*d* = 1.05 [95% CI: 0.34, 1.75], *P* = 0.0064), while adult and geriatrics performed comparably (*d* = -0.76 [95% CI: -1.44, -0.08], *P* = 0.75) (Figure 36A). These patterns were consistent across sexes (Figure 36B). Mid-age females (20.97 ± 10.29s) had longer decision times than adult females (9.05 ± 2.31s; *d* = -1.53 [95% CI: -2.53, -0.53], *P* = 0.0008), and trended slower than geriatric females (12.64 ± 5.19s; *d* = 0.94 [95% CI: -0.04, 1.92], *P* = 0.034). Similarly, mid-age males (20.06 ± 10.43s) were slower than adult males (9.25 ± 3.25s; *d* = -1.37 [95% CI: -2.37, -0.37], *P* = 0.0031) and geriatrics (11.28 ± 3.87s; *d* = 1.03 [95% CI: 0.02, 2.05], *P* = 0.028). No sex differences emerged within age groups (*d*'s = -0.07 to 0.28, *P*'s > 0.99) (Figure 36C).

These age-related patterns were reinforced during the test trials. Mid-age crickets (26.25 ± 16.89s) again took longer to decide than adults (13.73 ± 5.45s; *d* = -0.99 [95% CI: -1.65, -0.32], *P* = 0.0084) and geriatrics (16.11 ± 11.48s; *d* = 0.69 [95% CI: 0.03, 1.34], *P* = 0.012), while adults and geriatrics showed similar performance (*d* = -0.26 [95% CI: -0.89, 0.37], *P* > 0.99) (Figure 36D). Mid-age females (24.04 ± 17.18s) trended slower than adult females (12.09 ± 4.66s; *d* = -0.91 [95% CI: -1.83, 0.01], *P* = 0.046), but not geriatrics (14.45 ± 6.07s; *d* = 0.68 [95% CI: -0.28, 1.63], *P* = 0.16), while mid-age males (28.72 ± 17.23s) were markedly slower than both adult (15.36 ± 5.93s; *d* = -1.01 [95% CI: -1.97, -0.06], *P* = 0.028) and geriatric males (11.21 ± 1.98s; *d* = 1.31 [95% CI: 0.26, 2.36], *P* = 0.005) (Figure 36E). No within-group sex differences were detected (*d*'s = -0.59 to 0.68, *P*'s > 0.99) (Figure 36F).

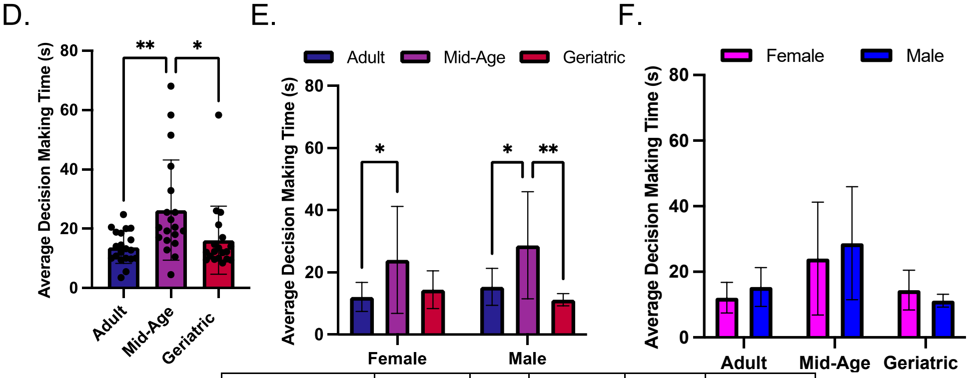
Prolonged time to punishment arm with the favorable vanilla scent in mid-age crickets was seen only during learning trials. Mid-age crickets required more time to reach the punishment arm (23.34 ± 12.33s) than both adults (12.50 ± 6.15s; *d* = -1.11 [95% CI: -1.91, -0.41], *P* = 0.0016) and geriatrics (14.65 ± 6.63s; *d* = 0.85 [95% CI: 0.14, 1.56], *P* = 0.018) (Figure 36G). In sex-stratified analyses, mid-age females (22.38 ± 10.25s) were slower than adults (11.47 ± 5.15s; *d* = -1.28 [95% CI: -2.30, -0.27], *P* = 0.034), while mid-age males (24.42 ± 14.99s) outpaced adults (13.43 ± 7.07s; *d* = -0.93 [95% CI: -1.91, 0.05], *P* = 0.034) and geriatrics (13.10 ± 5.49s; *d* = 0.95 [95% CI: -0.09, 1.98], *P* = 0.039) (Figure 36H). No sex differences were seen within any age group (*d*'s = -0.30 to 0.44, *P*'s > 0.99) (Figure 36I). However, during test trials, these age-related differences dissipated (*d*'s = -0.57 to 0.59, *P*'s = 0.50 to > 0.99) (Figure 36J), with mid-age females (25.47 ± 33.84s) and males (24.45 ± 21.41s) performing similarly to their peers (*d*'s = -0.56 to 0.80, *P*'s = 0.18 to 0.96) (Figure 36K), and no sex-based variation was detected (*d*'s = -0.50 to 0.47, *P*'s > 0.99) (Figure 36L).

Time to reward arm with the adverse cinnamon scent was consistently prolonged in mid-age crickets across both training and test trials. Mid-age crickets (19.61 ± 10.64s) required more time to reach the reward arm than both adults (8.54 ± 2.61s; *d* = -1.42 [95% CI: -2.12, -0.71], *P* < 0.0001) and geriatrics (10.93 ± 3.71s; *d* = 1.03 [95% CI: 0.32, 1.74], *P* = 0.014) (Figure 36M). Mid-age females (20.39 ± 11.54s) and males (18.73 ± 10.16s) were slower than their adult counterparts (females: 8.48 ± 2.48s; *d* = -1.37 [95% CI: -2.34, -0.39], *P* = 0.0010); males: 8.60 ± 2.86s; *d* = -1.33 [95% CI: -2.33, -0.34], *P* = 0.0071) (Figure 36N). No within-group sex differences were found (*d*'s = -0.04 to 0.17, *P*'s > 0.99) (Figure 36O).

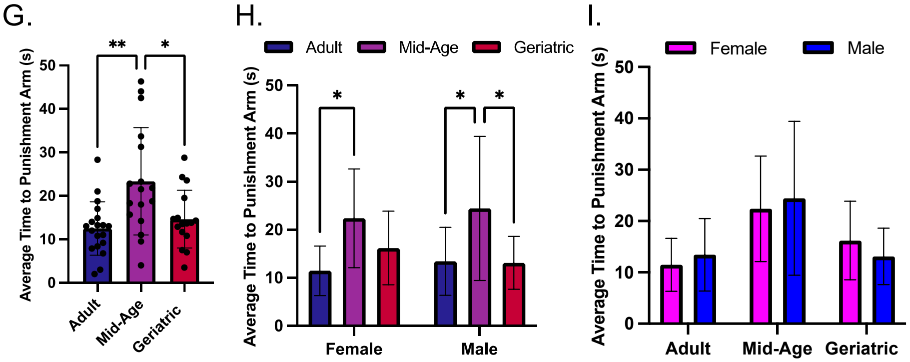
These patterns were replicated during test trials, with mid-age males (32.98 ± 16.87s) again showing delayed times compared to adults (15.42 ± 5.35s; *d* = -1.37 [95% CI: -2.37, -0.37], *P* = 0.0005) and geriatrics (11.23 ± 3.59s; *d* = 1.64 [95% CI: 0.54, 2.74], *P* < 0.0001), while mid-age females (22.61 ± 9.96s) trended higher than adults (12.97 ± 7.05s; *d* = -1.07 [95% CI: -2.01, -0.13], *P* = 0.066), but did not differ from geriatrics (15.31 ± 7.27s; *d* = 0.78 [95% CI: -0.18, 1.75], *P* = 0.24) (Figure 36P-Q). No sex differences were evident within age groups (*d*'s = -0.73 to 0.67, *P*'s = 0.061 to > 0.99) (Figure 36R).



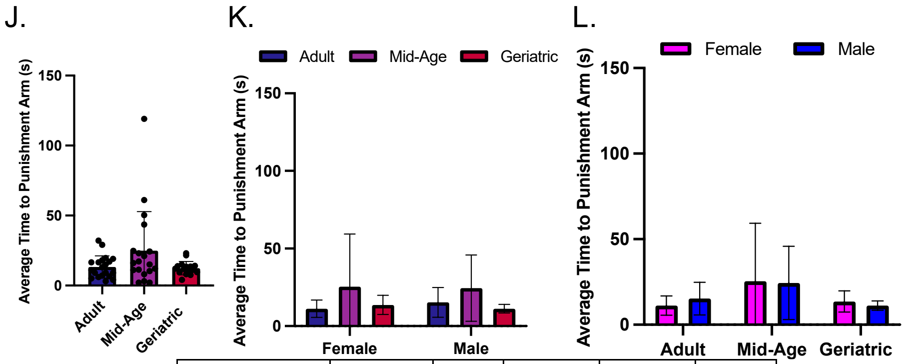
Source	SS	df	MS	*F*	*P*
Age	1341	2	670.3	14.54	<0.0001
Sex	6.46	1	6.46	0.14	0.71
Interaction	5.91	2	2.96	0.06	0.94
Residual	2259	49	46.09		
Total	3612	54			



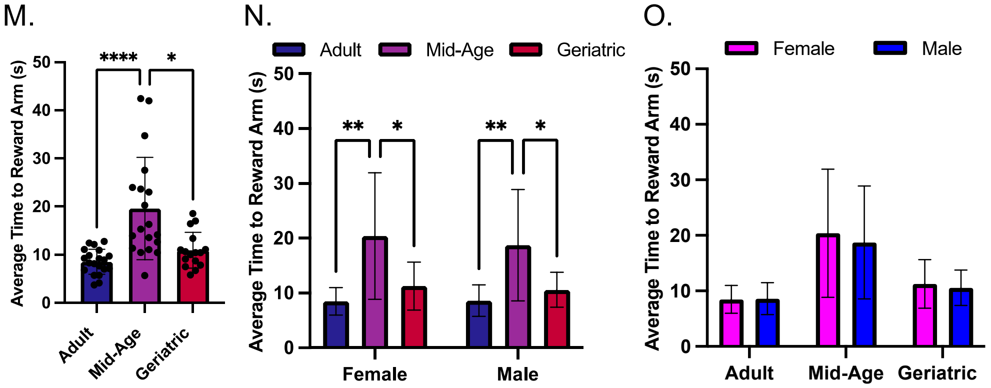
Source	SS	df	MS	*F*	*P*
Age	2121	2	1061	8.92	0.0005
Sex	33.50	1	33.50	0.28	0.60
Interaction	151.7	2	75.85	0.64	0.53
Residual	5828	49	118.9		
Total	8134	54			



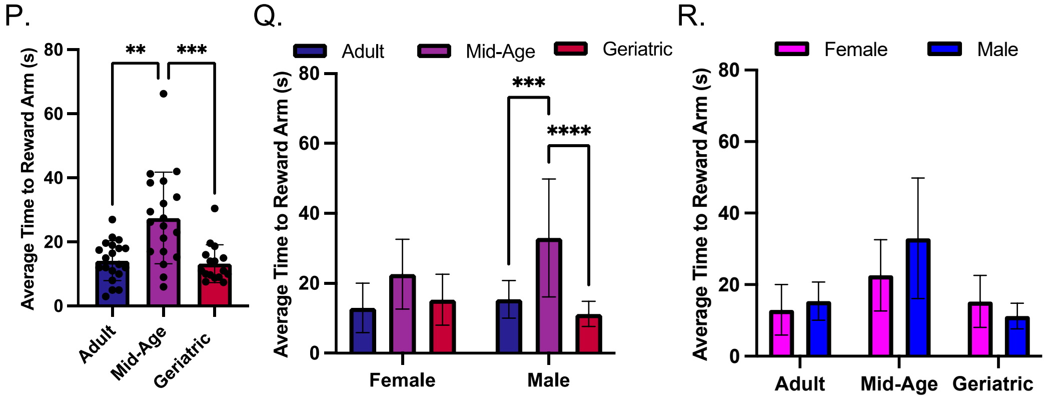
Source	SS	df	MS	*F*	*P*
Age	1170	2	585.0	7.28	0.0018
Sex	1.18	1	1.18	0.01	0.90
Interaction	71.87	2	35.94	0.45	0.64
Residual	3696	46	80.36		
Total	4939	51			



Source	SS	df	MS	*F*	*P*
Age	1821	2	910.4	2.90	0.06
Sex	0.66	1	0.66	0.002	0.96
Interaction	108.9	2	54.43	0.17	0.84
Residual	15403	49	314.3		
Total	17334	54			



Source	SS	df	MS	*F*	*P*
Age	1283	2	641.4	13.32	<0.0001
Sex	7.61	1	7.61	0.16	0.69
Interaction	7.67	2	3.84	0.08	0.92
Residual	2360	49	48.15		
Total	3658	54			



Source	SS	df	MS	*F*	*P*
Age	2445	2	1222	13.82	<0.0001
Sex	115.9	1	115.9	1.31	0.26
Interaction	458.1	2	229.1	2.59	0.09
Residual	4335	49	88.48		
Total	7354	54			

Figure 36. Age- and sex-related differences in decision-making time. (A-C) During main trials, mid-age crickets displayed longer average decision-making times compared to adult and geriatric cohorts, with consistent patterns in both females and males (A-B) and no within-sex differences (C). **(D-F)** This trend persisted during test trials, where mid-age crickets again required more time to decide compared to both adult and geriatrics; effects were robust across sexes (D-E), with no within-group sex differences observed (F). **(G-I)** Time to reach the punishment arm was elevated in mid-age crickets during main trials, relative to both adults and geriatrics, with consistent delays in females and males (G-H) and no sex-based variation (I). **(J-L)** No age- or sex-based differences emerged for punishment arm times during test trials. **(M-O)** Mid-age crickets showed prolonged times to reach the reward arm during main trials relative to other age groups; these differences were conserved across sexes (M-N), with no detectable sex effects (O). **(P-R)** In test trials, both female and male mid-age crickets again demonstrated longer reward arm times compared to adults and geriatrics, particularly in males (P-Q); within-group sex differences remained absent (R) (age groups = 16-20/cohort, $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$, $^{****}P < 0.0001$).

Detailed summary statistics can be found in Appendix 9. Table S1 presents age-related group summaries, while Table S2 provides age-related summaries stratified by sex.

Discussion.

Our study demonstrates that the house cricket (*Acheta domesticus*) can recapitulate key features of organismal aging, including lifespan modulation, cognitive decline, and locomotor impairment, and that these hallmarks are amenable to pharmacological intervention. Lifespan extension was achieved with each geroprotective compound (rapamycin, acarbose, and phenylbutyrate), with a combined SLAM regimen yielding a significant early-life survival benefit. Cognitive performance assays revealed age-related deficits in exploratory and anxiety-like behavior, as well as olfactory-driven decision-making, which were partially alleviated by interventions. Locomotor function deteriorated with age (notably in speed and endurance), but this too was improved by select treatments. Below, we discuss these findings in the context of aging biology, drawing comparisons to established models like *Drosophila* and mice, and highlighting sex-specific effects. We also address study limitations, including statistical power considerations, lack of histological analyses, and the need for a geropathology framework in crickets, and suggest directions for future research.

Lifespan extension with geroprotective interventions. The extension of cricket lifespan by rapamycin, acarbose, and phenylbutyrate reinforces the evolutionarily conserved efficacy of these compounds. All three agents are well-documented in mouse models for prolonging life through modulation of distinct aging pathways (Jiang et al., 2022). Rapamycin, an mTOR inhibitor, robustly extends lifespan even when administered in late-life (Wilkinson et al., 2012; Selvarani et al., 2020; Zhang et al., 2014) and delays multiple age-related pathologies across species. Acarbose, an α-glucosidase inhibitor, enhances male lifespan in mice by blunting postprandial glycemic spikes and attenuating insulin/IGF-1 signaling (Harrison et al., 2019). Phenylbutyrate, a histone deacetylase inhibitor, similarly increases longevity in *Drosophila* without compromising functional capacity (Kang et al., 2002). Our findings support these mechanisms: treated house crickets showed higher median survival than controls, confirming that the pro-longevity effects of mTORC1 inhibition, metabolic modulation, and epigenetic reprogramming translate to an invertebrate system.

To determine whether these effects were mediated by changes in food intake, a known modifier of aging, we evaluated survival outcomes using a Cox proportional hazards model that accounted for group-level food consumption. A key finding was that the survival benefits associated with rapamycin and phenylbutyrate remained robust even after adjusting for food intake. Notably, rapamycin-treated crickets consumed *less* food on average than controls, yet lived longer, underscoring the independent and durable benefits of pharmacologic intervention. Together, these findings affirm that lifespan extension in our model is not attributable to caloric restriction or differential nutritional exposure. Interestingly, the Cox model revealed inflated hazard ratios and confidence intervals for the interaction terms between food consumption and both rapamycin and phenylbutyrate. These unstable estimates likely stem from low variance in food intake within groups and from multicollinearity introduced by uniformly applied group-level feeding data. While these values should not be interpreted literally as multiplicative effects on mortality risk, their consistent directionality suggests a biological meaningful interaction: higher food consumption within these groups correlated with longer survival, hinting at a synergistic relationship between adequate nutrition and the efficacy of these drugs. By contrast, the absence of a food-treatment interaction for acarbose points toward a distinct, possibly nutrition-independent, mode of action.

Further refinement came from post-intermittent treatment survival tracking. After cessation of drug administration and a return to standard chow, rapamycin-treated crickets maintained a marked survival advantage over controls (median: 136 vs. 104 days). This durable benefit echoes mouse studies demonstrating persistent gains following short-term rapamycin exposure (Bitto et al., 2016) and supports the notion that brief interventions targeting mTORC1 can produce long-lasting alterations to the aging trajectory. In contrast, intermittent treatment with acarbose (91 days) or SLAM cocktail (89.5 days_ shortened survival relative to controls, suggesting that the benefits observed during treatment may not persist, or may even reverse, once the drug is withdrawn. Phenylbutyrate-treated individuals exhibited no difference from controls after treatment cessation (99.5 days), implying that its longevity effects may require sustained administration.

Sex-stratified analyses revealed further complexity. Rapamycin-treated males continued to show extended survival after intermittent treatment cessation (132.5 vs. 97 days), while females treated with acarbose or SLAM exhibited reduced longevity compared to untreated controls. Notably, phenylbutyrate-treated females outlived their male counterparts (116.5 vs. 83 days), an effect not observed in other treatment groups. These sex-specific trajectories align with mammalian data, where females generally respond more robustly to rapamycin and phenylbutyrate (Selvarani et al., 2020; Miller et al., 2014), while males show stronger responses to acarbose (Harrison et al., 2014; Herrera et al., 2020). In crickets, sex-based differences in drug metabolism, hormonal aging pathways, and even body composition (e.g., females tend to weigh more than males (Liao et al., 2025)), may modulate pharmacokinetics and treatment efficacy.

In support of these physiological differences, we observed sex-specific changes in somatic maintenance during intermittent treatment. Although overall percent weight change did not differ across treatment groups, females treated with acarbose gained substantially more weight than control females (29.2 vs. 9.3%), and within-treatment comparisons revealed greater weight gain in females than males across acarbose, rapamycin, and phenylbutyrate groups. These data suggest that drug-treated females preserved or even enhanced somatic mass during the drug delivery period, potentially reflecting improved metabolic resilience or differential allocation of energetic resources. Importantly, this somatic gain did not come at the cost of reduced lifespan, in fact, rapamycin- and phenylbutyrate-treated females showed enhanced survival, suggesting that weight maintenance and longevity were not inversely coupled. Ratgher, increased weight gain in females may confer improved somatic robustness or endocrine-mediated protection under treatment, consistent with prior reports that sex differences in insect lifespan are species- and context-dependent (Stillwell et al., 2010; Hopkins et al., 2021)

The combined SLAM cocktail, despite its theoretical synergy, did not extend maximum nor post-treatment lifespan beyond rapamycin, acarbose, or phenylbutyrate alone. This finding is consistent with prior mouse work showing that the SLAM cocktail improved multiple health metrics but did not exceed the lifespan benefits of single agents (Jiang et al., 2024). These results suggest that overlapping or even antagonistic effects may limit the efficacy of polypharmacy, especially when treatment is delivered intermittently or withdrawn prematurely. The front-loaded survival gain we observed with SLAM, an increased median but not maximum lifespan, may reflect early benefits without late-life resilience, a profile more consistent with healthsapn extension than true longevity gain.

In total, these findings support the conclusion that pharmacological interventions can meaningfully extend lifespan in crickets via mechanisms that are at least partially independent of energy intake. Rapamycin remains the most durable agent across both sexes and conditions, while phenylbutyrate confers selective benefit, especially in females. Acarbose and SLAM show more complex, possibly dose- or timing-dependent profiles. Importantly, the survival benefits observed are not artifacts of reduced food consumption and may instead reflect conserved biological programs of aging that can be manipulated across taxa. Future studies should further dissect how nutritional status and sex interact with geroprotective therapies to optimize treatment duration, combination, and timing for maximizing both healthspan and lifespan.

Cognitive aging and pharmacological preservation of function. Age-associated cognitive decline in house crickets was evident across multiple behavioral domains, consistent with patterns observed in vertebrate models. In the free-movement Y-maze, geriatric crickets displayed reduced behavioral complexity, reflected by a marked decrease in Shannon entropy and an increased reliance on repetitive turn sequences. These findings suggest a progressive shift toward stereotyped behavioral patterns with age, paralleling age-related cognitive rigidity reported in rodents and humans (Klanker et al., 2013),

Despite the apparent inflexibility in exploratory behavior, odor-guided decision-making remained a partially preserved and pharmacologically responsive cognitive domain. In the olfactory preference assay, aged crickets exhibited impaired attraction to a food-related odor (vanilla), indicating deficits in olfactory discrimination and possibly odor-memory integration. This impairment was ameliorated by administration of rapamycin and phenylbutyrate, both of which restored odor preference to levels comparable with those of young adults. Acarbose also improved olfactory performance, though to a lesser extent. These results demonstrate that modulation of mTOR, metabolic, and epigenetic pathways can attenuate specific features of cognitive aging in invertebrates.

Mechanistically, rapamycin is known to reduce is known to reduce neuroinflammation and enhance autophagic clearance of damaged proteins in aging mammalian brains (Selvarani et al., 2021; Svensson et al., 2024; Guan et al., 2009), while HDAC inhibitors like phenylbutyrate promote transcription of pro-cognitive genes and stabilize synaptic proteins (Guan et al., 2009; Kang et al., 2002). The efficacy of these compounds in preserving odor-driven behavior in crickets suggests that such pathways may be evolutionarily conserved, potentially acting through preservation of mushroom body plasticity or maintenance of cholinergic transmission (Scotto-Lomassese et al., 2003; Matsumoto & Mizunami 2000).

However, the SLAM drug cocktail, despite combining these compounds, did not outperform rapamycin or phenylbutyrate alone in cognitive rescue. This may reflect a ceiling effect, in which individual drugs already achieved maximal benefit through overlapping mechanisms or may indicate suboptimal synergy under the current dosing paradigm. Evidence from murine studies supports both interpretations: while drug combinations robustly modulate molecular markers of aging, their behavioral effects do not always exceed those of single agents (Jiang et al., 2024). Future work could test alternative dosing schedules, longer treatment durations, or combinatorial approaches with behavioral enrichment to identify conditions under which multi-drug regimens yield additive cognitive benefits.

Although olfactory behavior responded to treatment, Y-maze entropy and repetition patterns remained unaffected, suggesting that broader behavioral flexibility is less pharmacologically tractable in aged crickets. These results imply that while certain sensorimotor or motivational components of cognition, (e.g., odor-driven decision-making), retain plasticity in late life, higher-order executive processes may be constrained by age-related neuroanatomical remodeling. This is consistent with studies in *Drosophila*, where phenylbutyrate extended lifespan and preserved motor function only when administered continuously from early adulthood (Kang et al., 2002), highlighting the potential importance of early or lifelong intervention.

Supporting these behavioral data, open field tests revealed that aged crickets exhibited spatial restriction and avoidance of central zones, indicative of diminished exploratory drive and cognitive adaptability. These spatial biases were largely unresponsive to treatment, except for modest central zone engagement in rapamycin-treated males. This selective rescue reinforces the idea that not all cognitive dimensions are equally modifiable, with some requiring more sustained or targeted interventions.

Sex-based differences emerged as a secondary yet informative pattern. Aged males were disproportionately affected in the olfactory assay, exhibiting greater loss of odor preference than aged females. This mirrors observations in mice, where male-specific olfactory decline precedes broader cognitive impairment (Tzeng et al., 2021), and in humans, where olfactory loss and spatial memory deficits occur earlier and/or more severely in men (Kondo et al., 2020). Such patterns may be partially explained by hormonal neuroprotection, as estrogens support cholinergic signaling and synaptic health (Gibbs & Aggarwal 1998). Nevertheless, treatment efficacy in the current study was not strictly sex-dependent, suggesting that the primary determinants of cognitive rescue lie in drug-target interactions rather than in sex-specific biology.

Finally, the behavioral outcomes observed here likely reflect underlying neurobiological changes that are conserved across species. In insects, olfactory memory depends on cholinergic signaling within the mushroom bodies (Barnstedt et al., 2016), and age-related degradation of this system may contribute to the observed deficits. The ability of rapamycin and phenylbutyrate to preserve odor preference suggests neuroprotective action at the circuit or synaptic level. These findings position the cricket as a viable invertebrate model for probing the mechanisms of cognitive aging and testing interventions that may translate across phyla.

Locomotor decline with age and pharmacological modulation of physical frailty.

Locomotor function declined markedly with age in house crickets, validating this species as a model for assessing physical frailty. Geriatric crickets demonstrated reduced maximal running speed and treadmill endurance compared to younger cohorts, similar to well-documented age-related declines in gait speed, muscle power, and physical capacity observed across mammalian aging and frailty (Neff et al., 2013). Notably, this decline was not uniform across all motor domains: while running performance deteriorated in both sexes, jump performance decreased primarily in aged females. This secondary sex effect may reflect divergent resource allocation during reproductive aging, with females experiencing more rapid musculoskeletal degradation, reflecting earlier neuromuscular decline observed in females (Gordon et al., 2016).

Pharmacological intervention mitigated several aspects of locomotor aging. Both rapamycin and phenylbutyrate, alone or in combination (SLAM), restored maximal running speed in aged crickets to near-youthful levels. SLAM-treated individuals reached top speeds (~55 cm/s) comparable to young adults (~58 cm/s), and endurance was similarly extended across these groups. These effects were consistent across sexes, indicating preserved neuromuscular integrity. The efficacy of rapamycin aligns with rodent data showing its ability to preserve muscle function, fiber morphology, and endurance into late life (Neff et al., 2013). Phenylbutyrate-induced effects may involve enhanced oxidative stress resistance and metabolic efficiency via histone acetylation and transcriptional reprogramming. In contrast, acarbose failed to improve speed or endurance, despite its known lifespan-extending effects. This suggests that acarbose's metabolic benefits may not translate into immediate locomotor gains, highlighting a key dissociation between lifespan extension and physical function—a critical issue in geroscience.

Open field test metrics corroborated these findings. Aged crickets showed reduced total distance traveled, lower average velocity, and a sharp decline in running speeds. These deficits were selectively rescued by rapamycin, particularly in males, where walking speed and exploratory vigor approached those of young controls. Silhouette-based clustering of movement patterns confirmed this preservation of walking velocity. Interestingly, rapamycin-treated crickets also exhibited increased freezing episodes, likely reflecting pauses for active information gathering rather than immobility due to frailty, consistent with exploratory "checks" observed in invertebrate behavior (Kiuchi et al., 2023).

Jump performance, however, remained largely unresponsive to treatment. None of the interventions significantly improved maximal jump distance in aged crickets. This may reflect structural limitations, such as reduced exoskeletal elasticity or leg spring stiffness, that are not easily reversed by systemic metabolic interventions. Subtle, sex-specific trends were observed (e.g., acarbose slightly improving male jumps; rapamycin aiding female performance), but these did not survive correction for multiple comparisons. Jumping, a power-intensive behavior, may require longer or earlier intervention to affect musculoskeletal remodeling, or it may depend on anatomical features that are less plastic in late life.

Together, these results suggest that while endurance and speed, metrics reflecting metabolic output and neuromuscular coordination, are modifiable by interventions targeting nutrient-sensing and epigenetic pathways, power-based functions like jumping may be less tractable. This distinction mirrors findings in mammalian systems, where certain interventions preferentially affect mitochondrial function (endurance) or hypertrophy (strength), but rarely both (Heyne et al., 2024; Mesquita et al., 2021).

Our findings also underscore the importance of using multidimensional frailty indices in aging research. The open field test, treadmill assay, and jump task each captured distinct components of locomotor decline. For example, improvements in speed and endurance did not necessarily translate into gains in maximal power output. Such task-specific patterns align with geriatric assessments in humans and animal models, where physical performance involves a suite of interrelated but separable physiological systems.

Future work should explore prolonged or early-life administration of these compounds and expand behavioral assays to include climbing, geotaxis, or fine gait analyses, similar to protocols in *Drosophila* and mice (Liu et al., 2015; Motz 2005). The partially conserved responses across species support the hypothesis that core mechanisms of sarcopenia, neuromuscular aging, and locomotor decline are thus modifiable by shared interventions.

Age-related changes in exploratory drive and modulation by geroprotective interventions. Aging substantially altered the spatial structure and motivational dynamics of exploratory behavior in house crickets. In the open field test, geriatric individuals exhibited pronounced thigmotaxis, avoiding the central zone and restricting movement to the arena periphery. This age-dependent increase in centrophobia parallels patterns seen in aging rodents, where heightened wall-hugging reflects diminished exploratory drive or elevated anxiety-like states. While baseline wall-following is a species-typical behavior, its exaggeration in late life likely reflects altered risk assessment or reduced behavioral flexibility, possibly linked to energetic constraints or neurocognitive decline (Sanmartin-Villar & Jeanson 2021; Overman et al., 2022; Scharf & Farji-Brener 2024).

Among tested interventions, rapamycin uniquely mitigated this age-related spatial bias. Treated males displayed greater engagement with the center zone, suggesting partial restoration of exploratory motivation. Although the magnitude of change was modest, the directionality aligns with findings in aging humans, where physical robustness correlates with increased environmental engagement and reduced avoidance behavior (Monteiro et al., 2024; Turkmen et al., 2025). Neither phenylbutyrate, acarbose, nor the SLAM cocktail significantly influenced central zone activity, indicating that only specific pathways, such as those regulated by mTOR, may effectively modulate this facet of aging behavior.

Freezing behavior further distinguished the effects of treatment. While overall freezing episodes declined with age, rapamycin-treated crickets exhibited a paradoxical increase in freezing frequency. Rather than reflecting elevated fear or stress, this pattern is best interpreted as a resurgence of sensorimotor engagement. In active individuals, exploratory pauses punctuate locomotion, producing start-stop movement sequences characteristic of youthful behavior. Thus, the reappearance of these freezing events in rapamycin-treated crickets may reflect preserved behavioral reactivity and environmental scanning, rather than anxiety.

These findings support the utility of the open field assay as a multidimensional behavioral tool capable of detecting age-related declines in not only locomotor vigor, but also motivational state and spatial strategy. The observed increase in centrophobia and decline in freezing with age point to a broader shift in exploratory structure, while the selective reversal of these traits by rapamycin underscores the potential to pharmacologically modulate behavioral dimensions beyond speed or stamina. Importantly, these outcomes highlight that anxiety-like or avoidant behaviors, while challenging to disentangle from general hypoactivity, constitute a modifiable component of age-related frailty and cognitive decline.

The partial rescue observed with rapamycin also underscores a broader principle in geroscience: interventions that preserve physical capacity may secondarily support cognitive and motivational domains. Whether this effect stems from improved neuromuscular output, preserved neurotransmission, or enhanced energy availability remains to be determined, but these findings lay the groundwork for future mechanistic investigations into how physical and affective health intersect in aging invertebrates.

Cognitive decline with age as assessed by the escape learning paradigm. To assess age-related cognitive decline beyond spontaneous exploration, we employed a decision-based escape learning task requiring crickets to associate olfactory cues with differential outcomes. By pairing a naturally aversive odor with a positive outcome and a preferred odor with a negative one, the paradigm tested both associative learning and the ability to override instinctual preferences, a form of higher-order cognition. This assay reliably differentiated age groups across multiple cognitive domains.

Older crickets exhibited marked impairments in task acquisition, decision speed, and learning success. A substantial proportion of geriatric individuals failed to reach the learning criterion despite five days of training, while most young adults succeeded within 1–2 sessions. Even among those that learned, aged crickets required more trials and displayed prolonged decision-making latencies. Mid-aged crickets showed intermediate performance, with some exhibiting peak indecision. These results align with established patterns in vertebrate cognitive aging, where both learning efficiency and reaction times decline with age (Nolte et al., 2019; Murphy, 2019).

The cognitive deficits observed likely reflect underlying neurobiological aging. The task relied heavily on olfactory processing and the mushroom bodies, regions essential for learning and memory in insects. These brain structures undergo functional deterioration with age, including reduced synaptic plasticity and adult neurogenesis. The poor performance of geriatric crickets thus provides a behavioral correlate of neural aging and underscores the importance of cognitive phenotyping in invertebrate models.

Although our primary goal was to establish age-related sensitivity, the escape paradigm also raised important considerations for intervention studies. Due to its labor-intensive nature and low throughput, we ultimately excluded it from the main drug-testing pipeline, as systematic testing across all treatment groups was not feasible. Nevertheless, the escape paradigm validated cognitive decline as a measurable component of the cricket aging trajectory and highlighted the importance of including neurocognitive endpoints in healthspan assessments. Going forward, scalable cognitive assays, such as automated odor-choice devices, simplified learning paradigms, or group-based training, will be essential for integrating cognition into high-throughput intervention screens. Behavioral automation and computer vision-based scoring could transform tasks like this into practical tools for large-cohort studies.

Limitations and future directions. While this study establishes fundamental links between pharmacological interventions and aging phenotypes in house, several limitations must be acknowledged. First, although our behavioral assays were guided by feasibility and aligned with prior studies, they were not all formally powered to detect subtle drug effects. While power analyses were conducted for lifespan outcomes, future behavioral studies should incorporate simulation-based power calculations, such as Monte Carlo methods (Harrison et al., 2010), to model expected variability and determine optimal sample sizes for detecting moderate treatment effects (e.g., 10% improvements in entropy or center zone time). Prospective power planning will help ensure statistical confidence while balancing logistical feasibility.

Second, while our locomotor assays captured high-level metrics (distance, speed, bouts), and machine learning aided in walking–running classification, we did not quantify finer aspects of gait, such as stride length, inter-leg coordination, or postural control. Insects typically employ a stereotyped tripod gait (Naniwa et al., 2021), and deviations from this pattern could reveal early neuromuscular decline. Comparable to rodent models utilizing the CatWalk system and human studies examining gait variability (Plotnik et al., 2007), aged crickets may exhibit subtle motor deficits that are not evident in gross metrics alone. Future studies should integrate high-speed videography or sensor-equipped treadmills to extract gait parameters such as duty cycle, inter-leg phase, and body sway. Emerging methods in insect biomechanics (Barreto et al., 2021) and computer vision-based kinematic tracking (Mock et al., 2018) make this feasible. Such analyses could reveal whether treatments like rapamycin preserve not just how far aged crickets move, but *how* they move, offering more granular insight into locomotor aging and sarcopenia.

Third, our behavioral findings lack corresponding tissue-level validation. Incorporating immunohistochemistry and histological analysis will be critical to link functional preservation to underlying anatomical integrity. For example, staining for choline acetyltransferase (ChAT) in the mushroom bodies could reveal age-related loss of cholinergic neurons, key regulators of learning and memory in insects (Barnstedt et al., 2016), and determine whether treatments mitigate such loss. Similarly, HDAC2 expression, an epigenetic marker associated with synaptic repression and memory decline (Guan et al., 2009; Kang et al., 2002), could serve as a readout of transcriptional youthfulness. Preliminary data confirm cross-reactivity of both markers in cricket tissue (Figure 37), supporting feasibility.

Beyond the nervous system, histopathological analysis of gut, muscle, and reproductive tissues would clarify whether extended healthspan reflects slowed systemic degeneration. For instance, does rapamycin reduce lipofuscin buildup in aged muscle or preserve gut integrity? Such analyses would move the model toward a more integrative understanding of aging across organ systems.

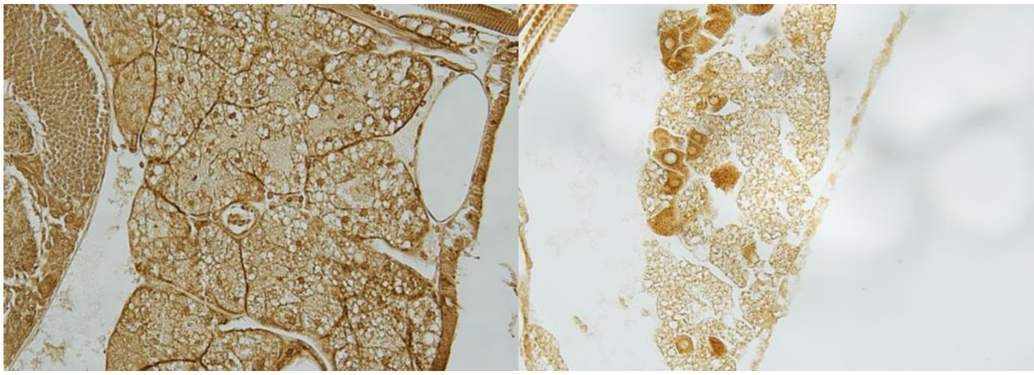


Figure 37. Positive IHC Staining at 20x Objective of HDAC2 and ChAT (left to right, longitudinal body sections)

To rigorously quantify tissue aging, we propose developing a standardized geropathology grading system for crickets, akin to those used in mouse models (Snyder et al., 2019; Snyder et al., 2023). This would entail defining hallmark lesions (e.g., neuronal vacuolization, muscle fragmentation, gut melanization) and assigning quantitative scores per tissue and age. Coupling these scores with behavioral readouts would strengthen causal links between histopathology and function. Such an atlas would also enable cross-species comparisons: if rapamycin reduces brain pathology in both mice and crickets, the translational relevance is greatly enhanced. Modern tools, including whole-organ imaging and AI-based scoring, can help overcome the challenges of applying pathology pipelines to small-bodied organisms (Kaeberlein et al., 2021). Integrating geropathology with functional metrics will create a more comprehensive picture of how interventions affect aging at both cellular and organismal scales.

Lastly, future studies should explore variations and expansions of the current work to address unanswered questions. One extension is examining additional interventions and combinations; for instance, adding a geroprotective compound like metformin or NAD^+ precursors to the cricket diet to see if they further boost healthspan, or testing whether shorter intermittent dosing of SLAM (as an early life “pulse” treatment) has lasting benefits, as has been suggested in mouse studies (Juricic et al., 2022).

In conclusion, this study demonstrates that pharmacological interventions known to extend lifespan in mammals, particularly rapamycin and phenylbutyrate, also preserve physiological and cognitive function in aging house crickets. These results point to evolutionarily conserved mechanisms underlying aging and intervention response. While limitations remain, including the need for deeper mechanistic validation and expanded behavioral metrics, the cricket model holds great promise for integrative aging research. Future efforts should focus on bridging behavioral, anatomical, and molecular data streams to form a unified aging phenotype. By doing so, the field can move beyond lifespan as a sole endpoint and toward a more comprehensive definition of healthspan, one that encompasses mobility, cognition, tissue integrity, and resilience.

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Appendix 1.

Experiment	Duration	Group	N	Sex		RR (95% CI)	*P*-Value
				Female[1] [N (%)]	Male [N (%)]		
Lifespan (Individual Drug Treatment)	07/02/24 to 11/01/24	Control[1]	86	52 (60.5)	34 (39.5)		
		Acarbose	77	41 (53.2)	36 (46.8)	1.14 (0.87, 1.50)	0.35
		Rapamycin	78	41 (52.6)	37 (47.4)	1.15 (0.66, 1.14)	0.31
		Phenylbutyrate	72	39 (54.2)	33 (45.8)	1.12 (0.68, 1.17)	0.43
Lifespan (Combination Treatment)	08/11/24 to 10/30/24	Control	85	42 (49.4)	43 (50.6)		
		SLAM	95	47 (49.5)	48 (50.5)	1.00 (0.75, 1.35)	0.99
Y-Maze	09/01/24	Juvenile	20	9 (45.0)	11 (55.0)		0.95
	11/19/24	Adult	21	9 (42.9)	12 (57.1)		
	12/03/24	Mid-Age	19	7 (36.8)	12 (63.2)		
	12/10/24	Geriatric	41	18 (43.9)	23 (56.1)		
	04/22/25	Control[1]	24	7 (29.2)	17 (70.8)		
		Acarbose	20	9 (45.0)	11 (55.0)	0.72 (0.36, 1.27)	0.28
		Rapamycin	23	9 (39.1)	14 (60.9)	0.80 (0.40, 1.43)	0.47
		Phenylbutyrate	21	11 (52.4)	10 (47.6)	0.62 (0.31, 1.11)	0.11
		SLAM	20	10 (50.0)	10 (50.0)	0.65 (0.33, 1.16)	0.16

Scent Preference Test	01/31/25	Adult	20	10 (50.0)	10 (50.0)		>0.99
	11/15/24	Mid-Age	20	10 (50.0)	10 (50.0)		
	11/29/24	Geriatric	16	8 (50.0)	8 (50.0)		
	04/23/25	Control[1]	19	5 (26.3)	14 (73.7)		
		Acarbose	20	10 (50.0)	10 (50.0)	0.57 (0.25, 1.16)	0.13
		Rapamycin	20	9 (45.0)	11 (55.0)	0.64 (0.28, 1.28)	0.22
		Phenylbutyrate	20	10 (50.0)	10 (50.0)	0.57 (0.25, 1.16)	0.13
		SLAM	20	9 (45.0)	11 (55.0)	0.64 (0.28, 1.28)	0.22
Open Field Test	12/02/24	Juvenile	30	15 (50.0)	15 (50.0)		0.94
	12/09/24	Adult	30	15 (50.0)	15 (50.0)		
	11/18/24	Geriatric	45	21 (46.7)	24 (53.3)		
	02/27/25	Control[1]	19	9 (47.4)	10 (52.6)	0.95 (0.49, 1.81)	0.95
		Acarbose	20	10 (50.0)	10 (50.0)		
		Rapamycin	20	10 (50.0)	10 (50.0)		
		Phenylbutyrate	20	10 (50.0)	10 (50.0)		
		SLAM	20	10 (50.0)	10 (50.0)		
Treadmill Assay	11/20/24	Adult	20	10 (50.0)	10 (50.0)		0.98
	12/04/24	Mid-Age	20	10 (50.0)	10 (50.0)		
	12/11/24	Geriatric	44	21 (47.7)	23 (52.3)		
	02/28/25	Control[1]	20	10 (50.0)	10 (50.0)		
		Acarbose	18	10 (55.6)	8 (44.4)	0.90 (0.49, 1.67)	0.73
		Rapamycin	20	10 (50.0)	10 (50.0)	1.00 (0.53, 1.88)	>0.99
		Phenylbutyrate	20	10 (50.0)	10 (50.0)	1.00 (0.53, 1.88)	>0.99
		SLAM	18	8 (44.4)	10 (55.6)	1.13 (0.58, 2.27)	0.73
Escape Paradigm	02/03/25 to 02/14/25	Adult	20	10 (50.0)	10 (50.0)		0.98
	11/18/24 to 11/29/24	Mid-Age	19	10 (52.6)	9 (47.4)		
	12/02/24 to 12/13/24	Geriatric	16	8 (50.0)	8 (50.0)		

Experimental cohorts demonstrated balanced sex distributions across all lifespan and behavioral assays conducted between June 2024 and April 2025. Sample sizes (N), sex distributions, relative risk (RR) estimates with 95% confidence intervals (CI), and p-values for comparisons of male representation across experimental groups. [1]Control groups and females served as the reference for effect size estimation and statistical testing. RR = relative risk; CI = confidence interval; P-values calculated using Fisher's exact test or chi-square test, as appropriate.

Appendix 2.

Overall	Mean (SD)					Adj. *P*-Value
	Control (N = 44)	Acarbose (N = 48)	Rapamycin (N = 46)	Phenylbutyrate (N = 48)	SLAM (N = 44)	
Weight (g)	0.51 (0.12)	0.55 (0.11)	0.49 (0.08)	0.47 (0.07)	0.44 (0.08)	0.83
Body Length (cm)	2.09 (0.21)	2.20 (0.19)	2.07 (0.17)	2.02 (0.18)	2.03 (0.19)	0.81
Antennal Length (cm)	2.45 (0.73)	2.83 (0.53)	2.61 (0.56)	2.58 (0.56)	2.59 (0.56)	0.58
Hind Leg Length (cm)	1.02 (0.08)	1.00 (0.08)	1.02 (0.08)	0.99 (0.08)	0.98 (0.08)	0.75
Femoral Cross-Sectional Area (cm^2)	0.03 (0.01)	0.03 (0.01)	0.03 (0.01)	0.02 (0.01)	0.02 (0.01)	0.96
Femoral Volume (cm^3)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.96
Femoral Surface Area to Volume	28.89 (2.31)	29.49 (1.95)	28.91 (2.35)	29.99 (2.38)	29.90 (2.40)	0.98
Hind Leg to Body Length	0.49 (0.05)	0.45 (0.05)	0.50 (0.05)	0.48 (0.05)	0.48 (0.05)	0.98
Antennal to Body Length	1.18 (0.28)	1.30 (0.22)	1.26 (0.23)	1.30 (0.25)	1.27 (0.22)	0.58
Hind Leg Length to Weight	2.25 (0.48)	2.09 (0.48)	2.10 (0.45)	2.17 (0.41)	2.45 (0.57)	0.99
Body Length to Weight	4.33 (0.92)	4.16 (0.89)	4.24 (0.81)	4.32 (0.74)	4.61 (0.88)	0.77
Hind Leg to Antennal Length	0.77 (0.52)	0.67 (0.17)	0.74 (0.23)	0.71 (0.21)	0.77 (0.32)	0.89
Antennal Length to Weight	5.12 (2.05)	5.42 (1.76)	5.57 (1.65)	5.68 (1.69)	5.85 (1.76)	>0.99

Female	Mean (SD)					Adj. *P*-Value
	Control (N = 17)	Acarbose (N = 27)	Rapamycin (N = 19)	Phenylbutyrate (N = 23)	SLAM (N = 19)	
Weight (g)	0.51 (0.12)	0.55 (0.11)	0.54 (0.11)	0.51 (0.11)	0.52 (0.10)	0.91
Body Length (cm)	2.09 (0.21)	2.20 (0.19)	2.13 (0.17)	2.06 (0.23)	2.11 (0.20)	0.85
Antennal Length (cm)	2.45 (0.73)	2.83 (0.53)	2.77 (0.33)	2.63 (0.53)	2.54 (0.67)	0.62
Hind Leg Length (cm)	0.99 (0.08)	1.04 (0.07)	1.03 (0.07)	0.99 (0.07)	1.03 (0.08)	0.69
Femoral Cross-Sectional Area (cm^2)	0.03 (0.00)	0.03 (0.00)	0.02 (0.00)	0.03 (0.01)	0.03 (0.00)	0.94
Femoral Volume (cm^3)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.94
Femoral Surface Area to Volume	27.95 (2.99)	27.32 (1.99)	28.14 (2.95)	27.79 (3.04)	27.17 (2.92)	0.97
Hind Leg to Body Length	0.80 (0.27)	0.86 (0.24)	0.81 (0.25)	0.86 (0.27)	0.88 (0.25)	0.95
Antennal to Body Length	1.18 (0.34)	1.30 (0.26)	1.30 (0.16)	1.28 (0.24)	1.21 (0.29)	0.72
Hind Leg Length to Weight	3.53 (1.65)	3.57 (1.19)	3.29 (1.09)	3.63 (1.45)	3.71 (1.43)	0.99
Body Length to Weight	4.33 (0.92)	4.16 (0.89)	4.07 (0.53)	4.21 (0.80)	4.20 (0.91)	0.95
Hind Leg to Antennal Length	0.77 (0.52)	0.67 (0.17)	0.62 (0.17)	0.67 (0.16)	0.91 (1.00)	0.93
Antennal Length to Weight	5.12 (2.05)	5.42 (1.76)	5.29 (0.93)	5.41 (1.46)	5.10 (1.67)	0.99

Male	Mean (SD)					Adj. *P*-Value
	Control (N = 27)	Acarbose (N = 21)	Rapamycin (N = 27)	Phenylbutyrate (N = 25)	SLAM (N = 25)	
Weight (g)	0.37 (0.08)	0.37 (0.08)	0.36 (0.06)	0.37 (0.06)	0.36 (0.07)	>0.99
Body Length (cm)	2.01 (0.20)	2.01 (0.14)	1.97 (0.12)	2.02 (0.13)	1.93 (0.17)	0.84
Antennal Length (cm)	2.57 (0.63)	2.70 (0.46)	2.60 (0.50)	2.78 (0.50)	2.64 (0.42)	0.88
Hind Leg Length (cm)	0.95 (0.12)	0.95 (0.08)	0.97 (0.08)	0.97 (0.07)	0.94 (0.07)	0.94
Femoral Cross-Sectional Area (cm^2)	0.02 (0.00)	0.02 (0.00)	0.02 (0.00)	0.02 (0.00)	0.02 (0.00)	0.97

Femoral Volume (cm^3)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	>0.99
Femoral Surface Area to Volume	28.08 (2.39)	28.04 (2.39)	28.24 (2.55)	28.00 (1.78)	28.03 (2.53)	>0.99
Hind Leg to Body Length	0.87 (0.24)	0.86 (0.24)	0.92 (0.26)	0.89 (0.25)	0.87 (0.22)	0.98
Antennal to Body Length	1.28 (0.29)	1.34 (0.21)	1.32 (0.24)	1.37 (0.22)	1.37 (0.19)	0.75
Hind Leg Length to Weight	4.95 (1.53)	4.87 (1.44)	5.20 (1.83)	4.98 (1.81)	4.79 (1.64)	0.99
Body Length to Weight	5.78 (1.78)	5.74 (1.49)	5.55 (0.78)	5.56 (1.04)	5.46 (0.95)	0.96
Hind Leg to Antennal Length	0.73 (0.35)	0.64 (0.15)	0.74 (0.35)	0.65 (0.17)	0.64 (0.17)	0.82
Antennal Length to Weight	7.21 (1.92)	7.68 (2.14)	7.35 (1.82)	7.58 (1.64)	7.44 (1.44)	0.96

Table S1. Morphological measurements across treatment groups. Body measurements were assessed in control and treatment groups (Acarbose, Rapamycin, Phenylbutyrate, and SLAM) overall, and separately by sex. Between-group comparisons were conducted using one-way ANOVA followed by pairwise comparisons approximating Dunnett's test (control vs. treatment comparisons only). *P*-values were adjusted for multiple comparisons across treatments within each measurement and Cohen's *d* with Hedges' *g* correction were calculated as the effect size with control as the reference group along with 95% confidence intervals obtained. No statistically significant differences were observed at α = 0.05 unless otherwise indicated.

	Control				Acarbose			
	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*
	Female	Male			Female	Male		
Weight (g)	0.51 (0.12)	0.37 (0.08)	1.32 (0.70, 2.21)	**0.006**	0.55 (0.11)	0.37 (0.08)	1.82 (1.23, 2.78)	**<0.0001**
Body Length (cm)	2.09 (0.21)	2.01 (0.20)	0.42 (-0.18, 1.01)	>0.99	2.2 (0.19)	2.01 (0.14)	1.10 (0.51, 1.91)	**0.0031**
Antennal Length (cm)	2.45 (0.73)	2.57 (0.63)	-0.19 (-0.82, 0.46)	>0.99	2.83 (0.53)	2.7 (0.46)	0.26 (-0.30, 0.86)	>0.99
Hind Leg Length (cm)	0.99 (0.08)	0.95 (0.12)	0.40 (-0.13, 0.97)	>0.99	1.04 (0.07)	0.95 (0.08)	1.18 (0.68, 1.79)	**0.0029**
Femoral Cross-Sectional Area (cm^2)	0.03 (0.00)	0.02 (0.00)	0.76 (0.28, 1.26)	0.52	0.03 (0.00)	0.02 (0.00)	0.43 (-0.15, 0.92)	>0.99
Femoral Volume (cm^3)	0.01 (0.00)	0.01 (0.00)	0.29 (-0.31, 0.90)	>0.99	0.01 (0.00)	0.01 (0.00)	0.69 (0.19, 1.28)	0.27
Femoral Surface Area to Volume	27.95 (2.99)	28.08 (2.39)	-0.05 (-0.60, 0.70)	>0.99	27.32 (1.99)	28.04 (2.39)	-0.33 (-0.87, 0.24)	>0.99
Hind Leg to Body Length	0.8 (0.27)	0.87 (0.24)	-0.27 (-0.99, 0.33)	>0.99	0.86 (0.24)	0.86 (0.24)	0.00 (-0.58, 0.56)	>0.99
Antennal to Body Length	1.18 (0.34)	1.28 (0.29)	-0.32 (-0.94, 0.28)	>0.99	1.3 (0.26)	1.34 (0.21)	-0.20 (-0.75, 0.32)	>0.99
Hind Leg Length to Weight	3.53 (1.65)	4.95 (1.53)	-0.89 (-1.78, -0.27)	0.095	3.57 (1.19)	4.87 (1.44)	-0.98 (-1.74, -0.40)	**0.024**
Body Length to Weight	4.33 (0.92)	5.78 (1.78)	-0.94 (-2.13, -0.61)	**0.013**	4.16 (0.89)	5.74 (1.49)	-1.31 (-2.97, -0.84)	**0.002**
Hind Leg to Antennal Length	0.77 (0.52)	0.73 (0.35)	0.09 (-0.62, 0.64)	>0.99	0.67 (0.17)	0.64 (0.15)	0.20 (-0.37, 0.72)	>0.99
Antennal Length to Weight	5.12 (2.05)	7.21 (1.92)	-1.04 (-1.90, -0.41)	**0.025**	5.42 (1.76)	7.68 (2.14)	-1.15 (-2.00, -0.59)	**0.0047**
	Rapamycin				Phenylbutyrate			
	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*
	Female	Male			Female	Male		

Weight (g)	0.54 (0.11)	0.36 (0.06)	1.98 (1.58, 2.69)	**<0.0001**	0.51 (0.11)	0.37 (0.06)	1.46 (0.81, 2.42)	**0.0002**
Body Length (cm)	2.13 (0.17)	1.97 (0.12)	1.10 (0.59, 1.74)	**0.018**	2.06 (0.23)	2.02 (0.13)	0.21 (-0.40, 0.85)	>0.99
Antennal Length (cm)	2.77 (0.33)	2.60 (0.50)	0.39 (-0.15, 0.87)	>0.99	2.63 (0.53)	2.78 (0.50)	-0.28 (-0.95, 0.27)	>0.99
Hind Leg Length (cm)	1.03 (0.07)	0.97 (0.08)	0.66 (0.14, 1.23)	0.37	0.99 (0.07)	0.97 (0.07)	0.21 (-0.33, 0.75)	>0.99
Femoral Cross-Sectional Area (cm^2)	0.02 (0.00)	0.02 (0.00)	0.30 (-0.36, 0.72)	>0.99	0.03 (0.01)	0.02 (0.00)	0.20 (-0.58, 0.56)	>0.99
Femoral Volume (cm^3)	0.01 (0.00)	0.01 (0.00)	0.17 (-0.38, 0.76)	>0.99	0.01 (0.00)	0.01 (0.00)	0.17 (-0.51, 0.65)	>0.99
Femoral Surface Area to Volume	28.14 (2.95)	28.24 (2.55)	-0.03 (-0.61, 0.65)	>0.99	27.79 (3.04)	28.0 (1.78)	-0.08 (-0.57, 0.57)	>0.99
Hind Leg to Body Length	0.81 (0.25)	0.92 (0.26)	-0.43 (-1.07, 0.11)	>0.99	0.86 (0.27)	0.89 (0.25)	-0.11 (-0.69, 0.45)	>0.99
Antennal to Body Length	1.30 (0.16)	1.32 (0.24)	-0.06 (-0.76, 0.46)	>0.99	1.28 (0.24)	1.37 (0.22)	-0.39 (-0.98, 0.21)	>0.99
Hind Leg Length to Weight	3.29 (1.09)	5.20 (1.83)	-1.20 (-1.82, -0.70)	**0.0009**	3.63 (1.45)	4.98 (1.81)	-0.81 (-1.45, -0.22)	0.081
Body Length to Weight	4.07 (0.53)	5.55 (0.78)	-2.13 (-2.83, -1.71)	**<0.0001**	4.21 (0.8)	5.56 (1.04)	-1.41 (-2.38, -0.87)	**0.0001**
Hind Leg to Antennal Length	0.62 (0.17)	0.74 (0.35)	-0.39 (-0.88, 0.12)	>0.99	0.67 (0.16)	0.65 (0.17)	0.10 (-0.48, 0.69)	>0.99
Antennal Length to Weight	5.29 (0.93)	7.35 (1.82)	-1.33 (-2.34, -0.75)	**<0.0001**	5.41 (1.46)	7.58 (1.64)	-1.37 (-2.15, -0.80)	**0.0002**

	Combined			
	Mean (SD)		*d* (95% CI)	*P*
	Female	Male		
Weight (g)	0.52 (0.10)	0.36 (0.07)	1.78 (1.19, 2.73)	**<0.0001**
Body Length (cm)	2.11 (0.20)	1.93 (0.17)	0.96 (0.37, 1.70)	**0.048**
Antennal Length (cm)	2.54 (0.67)	2.64 (0.42)	-0.19 (-0.73, 0.53)	>0.99
Hind Leg Length (cm)	1.03 (0.08)	0.94 (0.07)	1.13 (0.50, 2.00)	**0.009**
Femoral Cross-Sectional Area (cm^2)	0.03 (0.00)	0.02 (0.00)	0.67 (0.08, 1.39)	0.38
Femoral Volume (cm^3)	0.01 (0.00)	0.01 (0.00)	0.70 (0.06, 1.33)	0.44
Femoral Surface Area to Volume	27.17 (2.92)	28.03 (2.53)	-0.31 (-0.93, 0.25)	>0.99
Hind Leg to Body Length	0.88 (0.25)	0.87 (0.22)	0.05 (-0.51, 0.66)	>0.99
Antennal to Body Length	1.21 (0.29)	1.37 (0.19)	-0.65 (-1.25, -0.10)	0.62
Hind Leg Length to Weight	3.71 (1.43)	4.79 (1.64)	-0.69 (-1.42, -0.07)	0.31
Body Length to Weight	4.20 (0.91)	5.46 (0.95)	-1.33 (-2.76, -0.58)	**0.0008**
Hind Leg to Antennal Length	0.91 (1.00)	0.64 (0.17)	0.39 (-0.20, 0.79)	>0.99

Antennal Length to Weight	5.10 (1.67)	7.44 (1.44)	-1.49 (-2.56, -0.80)	**0.0003**

Table S2. Sex-specific differences within treatment groups for morphological measurements. Female and male crickets were compared within each treatment group (Control, Acarbose, Rapamycin, Phenylbutyrate, and Cocktail). Sex-specific comparisons were performed using Welch's t-tests (allowing unequal variances). Effect sizes were estimated with Cohen's *d* using bias-corrected Hedges' *g*, with 95% confidence intervals derived via bootstrapping (1,000 resamples). *P*-values were Bonferroni-adjusted within each treatment group.

Appendix 3.

Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value	Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value
43	NA	NA	NA	NA	NA	62	0.745	0.531	1.047	0.090	0.279
44	0.595	0.252	1.404	0.236	0.488	63	1.183	0.835	1.675	0.344	0.561
45	0.741	0.403	1.361	0.333	0.561	65	0.992	0.720	1.366	0.959	0.992
46	0.628	0.355	1.111	0.110	0.284	66	0.941	0.686	1.291	0.707	0.911
47	0.705	0.415	1.196	0.195	0.432	67	0.998	0.732	1.362	0.992	0.992
48	0.532	0.324	0.872	0.012	0.041	68	1.037	0.762	1.412	0.815	0.936
51	0.456	0.283	0.734	0.001	0.004	69	1.067	0.786	1.449	0.678	0.911
52	0.396	0.244	0.643	0.000	0.000	71	0.995	0.735	1.345	0.972	0.992
53	0.420	0.267	0.660	0.000	0.000	73	0.943	0.697	1.276	0.703	0.911
54	0.253	0.158	0.407	0.000	0.000	74	1.010	0.748	1.364	0.949	0.992
55	0.239	0.149	0.385	0.000	0.000	75	0.950	0.704	1.282	0.735	0.911
56	0.233	0.144	0.375	0.000	0.000	76	0.963	0.716	1.296	0.805	0.936
57	0.328	0.215	0.499	0.000	0.000	78	0.914	0.679	1.231	0.555	0.819
58	0.605	0.420	0.872	0.007	0.027	81	0.877	0.651	1.181	0.386	0.598
60	0.738	0.513	1.062	0.102	0.284	88	0.845	0.627	1.138	0.267	0.517
61	0.839	0.586	1.202	0.338	0.561	121	0.817	0.606	1.100	0.183	0.432

Table S1. Cumulative hazard ratios for SLAM-treated crickets compared to controls. Daily cumulative hazard ratios, 95% confidence intervals, and Benjamini-Hochberg false discovery rate (FDR)-adjusted *P*-values are reported for SLAM-treated crickets relative to control counterparts. All values are rounded to three decimal places. Timepoints with statistically detectable differences (adjusted $P < 0.05$) are highlighted in yellow.

Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value	Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value
43	1.000	0.091	11.028	1.000	1.000	80	1.045	0.751	1.453	0.794	0.917
44	0.939	0.326	2.704	0.907	0.980	84	1.120	0.806	1.557	0.500	0.701

Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value	Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value
45	0.460	0.184	1.149	0.096	0.230	85	0.996	0.718	1.381	0.979	1.000
46	0.408	0.187	0.890	0.024	0.080	86	0.929	0.669	1.289	0.658	0.872
47	1.128	0.575	2.216	0.726	0.901	88	0.870	0.625	1.210	0.407	0.628
48	0.723	0.373	1.401	0.337	0.560	89	0.887	0.639	1.231	0.473	0.677
49	0.757	0.426	1.345	0.343	0.566	91	0.822	0.591	1.142	0.242	0.445
50	0.883	0.508	1.536	0.660	0.872	92	0.837	0.603	1.161	0.286	0.489
51	1.072	0.639	1.797	0.793	0.917	95	0.849	0.613	1.176	0.325	0.544
52	0.852	0.514	1.411	0.533	0.738	96	0.787	0.567	1.092	0.151	0.320
53	1.082	0.653	1.793	0.759	0.911	100	0.807	0.583	1.118	0.198	0.403
54	0.956	0.591	1.547	0.854	0.936	101	0.817	0.591	1.131	0.224	0.428
55	1.239	0.776	1.978	0.368	0.589	103	0.778	0.562	1.077	0.131	0.298
56	0.773	0.495	1.206	0.256	0.453	105	0.786	0.568	1.088	0.146	0.315
57	0.943	0.620	1.435	0.786	0.917	106	0.744	0.537	1.031	0.076	0.193
58	0.872	0.581	1.309	0.509	0.709	108	0.753	0.544	1.042	0.087	0.214
59	0.983	0.661	1.464	0.934	0.981	111	0.760	0.549	1.051	0.097	0.230
60	0.983	0.664	1.455	0.932	0.981	112	0.707	0.510	0.979	0.037	0.111
61	0.958	0.653	1.406	0.828	0.933	115	0.638	0.459	0.886	0.007	0.039
62	1.019	0.697	1.490	0.922	0.981	116	0.609	0.438	0.848	0.003	0.029
63	1.106	0.763	1.604	0.596	0.805	118	0.585	0.420	0.814	0.001	0.018
64	1.062	0.733	1.537	0.751	0.911	121	0.624	0.451	0.863	0.004	0.031
65	1.061	0.733	1.535	0.754	0.911	128	0.633	0.458	0.874	0.005	0.033
66	1.184	0.817	1.715	0.372	0.591	130	0.706	0.513	0.971	0.032	0.100
67	1.428	0.986	2.069	0.059	0.159	133	0.706	0.514	0.971	0.032	0.100
68	1.390	0.964	2.002	0.077	0.193	136	0.659	0.480	0.907	0.010	0.045
69	1.252	0.882	1.776	0.209	0.414	137	0.672	0.490	0.923	0.014	0.055
70	1.248	0.879	1.771	0.215	0.417	141	0.643	0.468	0.882	0.006	0.036
71	1.139	0.802	1.616	0.468	0.677	147	0.610	0.443	0.839	0.002	0.029
72	1.034	0.733	1.459	0.850	0.936	149	0.622	0.453	0.854	0.003	0.029

Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value	Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value
73	1.028	0.733	1.440	0.874	0.953	150	0.629	0.458	0.863	0.004	0.031
74	1.150	0.822	1.610	0.414	0.630	152	0.635	0.463	0.871	0.005	0.033
75	1.046	0.749	1.461	0.792	0.917	154	0.640	0.467	0.877	0.006	0.036
77	1.042	0.747	1.453	0.809	0.920	161	0.622	0.453	0.852	0.003	0.029
78	0.950	0.682	1.325	0.764	0.911	162	0.632	0.462	0.867	0.004	0.031
79	1.043	0.750	1.451	0.802	0.920	164	0.635	0.463	0.869	0.005	0.033

Table S2. Cumulative hazard ratios for acarbose-treated crickets compared to controls. This table presents the daily cumulative hazard ratios, 95% confidence intervals, and Benjamini-Hochberg false discovery rate (FDR)-adjusted *P*-values for acarbose-treated versus control crickets. Values are rounded to three decimal places. Yellow highlights denote timepoints with statistically detectable differences (adjusted $P < 0.05$) after multiple comparison correction.

Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value	Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value
43	1.000	0.063	15.988	1.000	1.000	80	0.885	0.634	1.235	0.472	0.677
44	1.423	0.292	6.940	0.662	0.872	84	0.948	0.680	1.323	0.756	0.911
45	0.359	0.124	1.044	0.060	0.160	85	0.856	0.615	1.191	0.355	0.574
46	0.673	0.251	1.801	0.430	0.641	86	0.866	0.623	1.205	0.393	0.620
47	0.889	0.403	1.960	0.770	0.911	88	0.870	0.625	1.210	0.407	0.628
48	0.649	0.313	1.346	0.245	0.445	89	0.798	0.573	1.111	0.182	0.374
49	0.680	0.352	1.315	0.251	0.452	91	0.812	0.584	1.129	0.215	0.417
50	0.933	0.499	1.746	0.829	0.933	92	0.818	0.589	1.137	0.232	0.436
51	0.854	0.481	1.518	0.591	0.803	95	0.822	0.592	1.142	0.243	0.445
52	0.552	0.321	0.949	0.032	0.100	96	0.826	0.595	1.148	0.255	0.453
53	0.682	0.405	1.149	0.151	0.320	100	0.763	0.549	1.063	0.110	0.255
54	0.528	0.323	0.861	0.011	0.046	101	0.715	0.513	0.997	0.048	0.136
55	0.684	0.435	1.077	0.101	0.237	103	0.701	0.505	0.974	0.034	0.103
56	0.762	0.488	1.190	0.232	0.436	105	0.711	0.512	0.987	0.042	0.123
57	1.068	0.682	1.673	0.772	0.911	106	0.677	0.488	0.940	0.020	0.073
58	1.014	0.659	1.561	0.948	0.989	108	0.688	0.496	0.954	0.025	0.082

Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value	Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value
59	1.163	0.763	1.774	0.482	0.685	111	0.645	0.464	0.897	0.009	0.042
60	0.974	0.646	1.468	0.899	0.976	112	0.662	0.477	0.918	0.013	0.052
61	0.939	0.629	1.401	0.757	0.911	115	0.677	0.489	0.938	0.019	0.071
62	1.089	0.730	1.625	0.674	0.882	116	0.683	0.493	0.946	0.022	0.078
63	1.038	0.705	1.529	0.850	0.936	118	0.688	0.497	0.952	0.024	0.080
64	1.001	0.681	1.470	0.997	1.000	121	0.646	0.466	0.894	0.009	0.042
65	1.005	0.684	1.476	0.979	1.000	128	0.655	0.473	0.906	0.011	0.046
66	1.037	0.708	1.520	0.852	0.936	130	0.727	0.526	1.004	0.053	0.147
67	1.278	0.873	1.871	0.207	0.414	133	0.725	0.526	1.000	0.050	0.140
68	1.164	0.801	1.691	0.427	0.640	136	0.723	0.524	0.998	0.048	0.136
69	1.095	0.763	1.572	0.622	0.834	137	0.671	0.485	0.926	0.015	0.057
70	1.003	0.698	1.441	0.986	1.000	141	0.640	0.463	0.884	0.007	0.039
71	0.955	0.665	1.372	0.805	0.920	147	0.652	0.473	0.900	0.009	0.042
72	0.881	0.617	1.259	0.486	0.686	149	0.656	0.476	0.905	0.010	0.045
73	0.899	0.637	1.269	0.546	0.751	150	0.659	0.478	0.909	0.011	0.046
74	1.010	0.716	1.424	0.954	0.991	152	0.615	0.445	0.849	0.003	0.029
75	0.825	0.587	1.158	0.266	0.463	154	0.583	0.422	0.806	0.001	0.018
77	0.807	0.577	1.128	0.209	0.414	161	0.555	0.402	0.766	0.000	0.000
78	0.816	0.584	1.141	0.234	0.436	162	0.506	0.366	0.701	0.000	0.000
79	0.885	0.634	1.236	0.472	0.677	164	0.486	0.351	0.674	0.000	0.000

Table S3. Cumulative hazard ratios for phenylbutyrate-treated crickets compared to controls. Cumulative hazard ratios, 95% confidence intervals, and Benjamini-Hochberg false discovery rate (FDR)-adjusted *P*-values are shown for phenylbutyrate-treated crickets relative to controls, calculated at each daily timepoint. Results are rounded to three decimal places. Yellow highlighted cells indicate adjusted *P*-values below the threshold for statistical detectability (FDR < 0.05).

Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value	Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value
43	1.000	0.063	15.988	1.000	1.000	80	0.685	0.483	0.971	0.034	0.103
44	1.011	0.319	3.200	0.985	1.000	84	0.728	0.519	1.023	0.067	0.172

Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value	Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value
45	0.476	0.178	1.273	0.139	0.306	85	0.742	0.529	1.041	0.084	0.209
46	0.481	0.205	1.130	0.093	0.226	86	0.704	0.503	0.987	0.042	0.123
47	0.877	0.423	1.817	0.724	0.901	88	0.718	0.513	1.006	0.054	0.148
48	0.637	0.329	1.233	0.181	0.374	89	0.725	0.518	1.015	0.061	0.161
49	1.070	0.564	2.029	0.836	0.936	91	0.729	0.521	1.021	0.066	0.172
50	0.847	0.470	1.525	0.579	0.792	92	0.678	0.484	0.949	0.024	0.080
51	0.978	0.564	1.696	0.936	0.981	95	0.643	0.458	0.902	0.011	0.046
52	0.753	0.445	1.273	0.289	0.489	96	0.660	0.471	0.923	0.015	0.057
53	0.806	0.480	1.353	0.414	0.630	100	0.674	0.482	0.942	0.021	0.076
54	0.811	0.485	1.357	0.426	0.640	101	0.680	0.487	0.950	0.024	0.080
55	1.022	0.633	1.650	0.930	0.981	103	0.653	0.468	0.911	0.012	0.049
56	0.932	0.585	1.485	0.767	0.911	105	0.613	0.439	0.857	0.004	0.031
57	1.385	0.869	2.207	0.171	0.359	106	0.639	0.459	0.891	0.008	0.042
58	0.917	0.591	1.422	0.697	0.900	108	0.600	0.430	0.837	0.003	0.029
59	1.083	0.712	1.648	0.709	0.901	111	0.614	0.440	0.855	0.004	0.031
60	0.927	0.614	1.400	0.720	0.901	112	0.623	0.447	0.867	0.005	0.033
61	1.083	0.719	1.631	0.704	0.900	115	0.635	0.456	0.884	0.007	0.039
62	1.213	0.805	1.828	0.356	0.574	116	0.639	0.459	0.889	0.008	0.042
63	1.357	0.901	2.043	0.144	0.314	118	0.642	0.462	0.893	0.009	0.042
64	1.376	0.916	2.066	0.124	0.285	121	0.607	0.436	0.845	0.003	0.029
65	1.020	0.681	1.527	0.923	0.981	128	0.572	0.410	0.797	0.001	0.018
66	0.927	0.629	1.365	0.700	0.900	130	0.647	0.467	0.896	0.009	0.042
67	1.082	0.742	1.579	0.682	0.887	133	0.604	0.436	0.838	0.003	0.029
68	1.225	0.841	1.785	0.290	0.489	136	0.611	0.441	0.847	0.003	0.029
69	1.327	0.912	1.929	0.139	0.306	137	0.621	0.448	0.859	0.004	0.031
70	1.148	0.792	1.664	0.467	0.677	141	0.629	0.455	0.871	0.005	0.033
71	1.155	0.798	1.672	0.444	0.657	147	0.634	0.458	0.877	0.006	0.036
72	1.225	0.848	1.771	0.280	0.484	149	0.591	0.427	0.819	0.002	0.029

Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value	Day	Hazard Ratio	Lower 95% CI	Upper 95% CI	*P*-value	Adj *P*-value
73	1.191	0.827	1.717	0.348	0.569	150	0.560	0.404	0.777	0.001	0.018
74	1.069	0.747	1.529	0.716	0.901	152	0.574	0.415	0.794	0.001	0.018
75	0.816	0.572	1.165	0.263	0.462	154	0.581	0.421	0.804	0.001	0.018
77	0.860	0.607	1.218	0.396	0.620	161	0.569	0.412	0.786	0.001	0.018
78	0.803	0.567	1.137	0.216	0.417	162	0.579	0.420	0.800	0.001	0.018
79	0.769	0.545	1.086	0.136	0.306	164	0.583	0.422	0.804	0.001	0.018

Table S4. Cumulative hazard ratios for rapamycin-treated crickets compared to controls. Daily cumulative hazard ratios, 95% confidence intervals, and Benjamini-Hochberg false discovery rate (FDR)-adjusted *P*-values are listed for rapamycin-treated crickets in comparison to controls. All values are reported to three decimal places. Timepoints showing statistically detectable differences ($P < 0.05$) are highlighted in yellow following FDR correction.

Appendix 4.

<table>
<tr><td colspan="5">Proportion of repetitive tetragrams (Overall Data)</td></tr>
<tr><td>Group</td><td>N</td><td>Mean (SD)</td><td>Cohen’s <i>d</i> vs. Control (95% CI)</td><td><i>P</i>-value vs. Control</td></tr>
<tr><td>Juvenile</td><td>20</td><td>0.31 (0.27)</td><td>-0.04 (-0.58, 0.50)</td><td>0.94</td></tr>
<tr><td>Adult</td><td>21</td><td>0.22 (0.13)</td><td>-0.50 (-1.03, 0.02)</td><td>0.069</td></tr>
<tr><td>Mid-Age</td><td>19</td><td>0.39 (0.28)</td><td>0.27 (-0.23, 0.76)</td><td>0.32</td></tr>
<tr><td>Geriatric</td><td>41</td><td>0.32 (0.23)</td><td>Reference</td><td>Reference</td></tr>
<tr><td colspan="5">Proportion of repetitive tetragrams (Male Data)</td></tr>
<tr><td>Group</td><td>N</td><td>Mean (SD)</td><td>Cohen’s <i>d</i> vs. Control (95% CI)</td><td><i>P</i>-value vs. Control</td></tr>
<tr><td>Juvenile</td><td>11</td><td>0.29 (0.24)</td><td>-0.16 (-0.89, 0.58)</td><td>0.66</td></tr>
<tr><td>Adult</td><td>12</td><td>0.21 (0.14)</td><td>-0.42 (-1.44, 0.61)</td><td>0.40</td></tr>
<tr><td>Mid-Age</td><td>12</td><td>0.51 (0.27)</td><td>0.88 (-0.17, 1.92)</td><td>0.090</td></tr>
<tr><td>Geriatric</td><td>23</td><td>0.29 (0.22)</td><td>Reference</td><td>Reference</td></tr>
<tr><td colspan="5">Proportion of repetitive tetragrams (Female Data)</td></tr>
<tr><td>Group</td><td>N</td><td>Mean (SD)</td><td>Cohen’s <i>d</i> vs. Control (95% CI)</td><td><i>P</i>-value vs. Control</td></tr>
<tr><td>Juvenile</td><td>9</td><td>0.33 (0.30)</td><td>0.06 (-0.66, 0.77)</td><td>0.88</td></tr>
<tr><td>Adult</td><td>9</td><td>0.17 (0.12)</td><td>-0.67 (-1.38, 0.05)</td><td>0.075</td></tr>
<tr><td>Mid-Age</td><td>7</td><td>0.49 (0.22)</td><td>0.73 (0.01, 1.45)</td><td>0.039</td></tr>
<tr><td>Geriatric</td><td>18</td><td>0.32 (0.25)</td><td>Reference</td><td>Reference</td></tr>
</table>

Table S1. Age-related differences in the proportion of repetitive tetragrams in the Y-maze across all crickets and by sex. Mean proportion of repetitive tetragrams and standard deviation (SD) for each group. Effect sizes were calculated using Cohen’s *d* with Hedges’ *g* bias correction for small sample sizes and 95% confidence intervals (CI), using geriatric crickets as the reference group. Adjusted *P*-values reflect comparisons against the geriatric cohort. N = sample size per group.

Group	Mean (SD)		Cohen’s *d* (95% CI)	*P*-value
	Male	Female		
Juvenile	0.29 (0.24)	0.33 (0.30)	–0.14 (–0.94, 0.67)	0.73
Adult	0.21 (0.14)	0.17 (0.12)	0.33 (–0.52, 1.17)	0.43
Mid-Age	0.51 (0.27)	0.49 (0.22)	0.08 (–0.82, 0.99)	0.85
Geriatric	0.29 (0.22)	0.32 (0.25)	–0.12 (–0.68, 0.45)	0.67

Table S2. Within-group sex differences in the proportion of repetitive tetragrams across age cohorts. Comparison of mean proportion of repetitive tetragrams and standard deviation (SD) between males and females within each group. Effect sizes were calculated using Cohen’s *d* with Hedges’ *g* bias correction for small sample sizes and 95% confidence intervals (CI). Positive values indicate higher male means; negative values indicate higher female means. *P*-values were adjusted using Bonferroni correction.

<table>
<tr><td colspan="5">Proportion of repetitive tetragrams (Overall Data)</td></tr>
<tr><td>Group</td><td>N</td><td>Mean (SD)</td><td>Cohen’s <i>d</i> vs. Control (95% CI)</td><td><i>P</i>-value vs. Control</td></tr>
<tr><td>Control</td><td>22</td><td>0.30 (0.29)</td><td>—</td><td>—</td></tr>
<tr><td>Acarbose</td><td>20</td><td>0.30 (0.17)</td><td>0.00 (-0.61, 0.60)</td><td>0.63</td></tr>
<tr><td>Rapamycin</td><td>22</td><td>0.28 (0.27)</td><td>-0.06 (-0.65, 0.53)</td><td>0.79</td></tr>
<tr><td>Phenylbutyrate</td><td>21</td><td>0.29 (0.20)</td><td>-0.05 (-0.64, 0.55)</td><td>0.71</td></tr>
<tr><td>Combined</td><td>20</td><td>0.34 (0.18)</td><td>0.15 (-0.46, 0.76)</td><td>0.28</td></tr>
<tr><td colspan="5">Proportion of repetitive tetragrams (Female Data)</td></tr>
<tr><td>Group</td><td>N</td><td>Mean (SD)</td><td>Cohen’s <i>d</i> vs. Control (95% CI)</td><td><i>P</i>-value vs. Control</td></tr>
<tr><td>Control</td><td>7</td><td>0.35 (0.42)</td><td>—</td><td>—</td></tr>
<tr><td>Acarbose</td><td>9</td><td>0.36 (0.18)</td><td>0.04 (–0.95, 1.02)</td><td>0.79</td></tr>
<tr><td>Rapamycin</td><td>9</td><td>0.32 (0.37)</td><td>–0.05 (–1.01, 0.92)</td><td>0.91</td></tr>
<tr><td>Phenylbutyrate</td><td>11</td><td>0.36 (0.24)</td><td>0.04 (–0.91, 0.98)</td><td>0.62</td></tr>
<tr><td>Combined</td><td>10</td><td>0.33 (0.22)</td><td>–0.06 (–1.05, 0.92)</td><td>0.62</td></tr>
<tr><td colspan="5">Proportion of repetitive tetragrams (Male Data)</td></tr>
<tr><td>Group</td><td>N</td><td>Mean (SD)</td><td>Cohen’s <i>d</i> vs. Control (95% CI)</td><td><i>P</i>-value vs. Control</td></tr>
<tr><td>Control</td><td>15</td><td>0.28 (0.21)</td><td>—</td><td>—</td></tr>
<tr><td>Acarbose</td><td>11</td><td>0.25 (0.16)</td><td>–0.15 (–0.93, 0.63)</td><td>0.88</td></tr>
<tr><td>Rapamycin</td><td>13</td><td>0.26 (0.18)</td><td>–0.11 (–0.86, 0.63)</td><td>0.63</td></tr>
<tr><td>Phenylbutyrate</td><td>10</td><td>0.21 (0.13)</td><td>–0.36 (–1.17, 0.45)</td><td>0.74</td></tr>
<tr><td>Combined</td><td>10</td><td>0.34 (0.15)</td><td>0.33 (–0.48, 1.14)</td><td>0.32</td></tr>
</table>

Table S3. Treatment-related differences in the proportion of repetitive tetragrams in the Y-maze across all crickets and by sex. Mean proportion of repetitive tetragrams and standard deviation (SD) for each group. Effect sizes were calculated using Cohen's *d* with Hedges' *g* bias correction for small sample sizes and 95% confidence intervals (CI), using the control cohort as the reference group. Adjusted *P*-values reflect comparisons against the control cohort. N = sample size per group.

Proportion of repetitive tetragrams				
	Mean (SD)		*d* (95% CI)	Adj. *P*-Value
Group	Male	Female		
Control	0.28 (0.21)	0.35 (0.42)	–0.23 (–1.13, 0.67)	0.87
Acarbose	0.25 (0.16)	0.36 (0.18)	–0.63 (–1.54, 0.27)	0.51
Rapamycin	0.26 (0.18)	0.32 (0.37)	–0.24 (–1.09, 0.62)	0.95
Phenylbutyrate	0.21 (0.13)	0.36 (0.24)	–0.74 (–1.63, 0.15)	0.51
SLAM	0.34 (0.15)	0.33 (0.22)	0.05 (–0.83, 0.93)	0.87

Table S4. Within-group sex differences in the proportion of repetitive tetragrams across treatment cohorts. Comparison of mean proportion of repetitive tetragrams and standard deviation (SD) between males and females within each group. Effect sizes were calculated using Cohen's *d* with Hedges' *g* bias correction for small sample sizes and 95% confidence intervals (CI). Positive values indicate higher male means; negative values indicate higher female means. *P*-values were adjusted using Bonferroni correction.

Proportion of repetitive to varied transitions (Overall Data)				
Group	N	Mean (SD)	Cohen's *d* vs. Control (95% CI)	*P*-value vs. Control
Juvenile	20	0.41 (0.80)	–0.10 (–0.63, 0.44)	0.757
Adult	21	0.14 (0.12)	–0.67 (–1.35, 0.01)	0.001
Mid-Age	19	1.39 (2.09)	0.72 (0.16, 1.28)	0.076
Geriatric	41	0.47 (0.54)	Reference	Reference
Proportion of repetitive to varied transitions (Male Data)				
Group	N	Mean (SD)	Cohen's *d* vs. Control (95% CI)	*P*-value vs. Control
Juvenile	11	0.63 (1.03)	0.19 (–0.53, 0.91)	0.654
Adult	12	0.06 (0.06)	–0.65 (–1.63, 0.33)	0.008
Mid-Age	12	1.41 (1.92)	0.74 (0.02, 1.46)	0.128
Geriatric	23	0.48 (0.67)	Reference	Reference
Proportion of repetitive to varied transitions (Female Data)				
Group	N	Mean (SD)	Cohen's *d* vs. Control (95% CI)	*P*-value vs. Control
Juvenile	9	0.14 (0.18)	–1.14 (–2.00, –0.29)	0.002
Adult	9	0.28 (0.27)	–1.02 (–2.07, 0.03)	0.070
Mid-Age	7	1.35 (2.53)	0.03 (–0.91, 0.96)	0.96
Geriatric	18	0.47 (0.31)	Reference	Reference

Table S5. Age-related differences in the proportion of repetitive to varied transitions in the Y-maze across all crickets and by sex. Mean proportion of repetitive to varied transitions and standard deviation (SD) for each group. Effect sizes were calculated using Cohen's *d* with Hedges' *g* bias correction for small sample sizes and 95% confidence intervals (CI), using the geriatric cohort as the reference group. Adjusted *P*-values reflect comparisons against the geriatric cohort. N = sample size per group.

Group	Mean (SD)		Cohen's *d* (95% CI)	*P*-value
	Male	Female		
Juvenile	0.63 (1.03)	0.14 (0.18)	0.60 (–0.30, 1.51)	0.15
Adult	0.10 (0.14)	0.28 (0.27)	–1.02 (–2.07, 0.03)	0.07
Mid-Age	1.41 (1.92)	1.35 (2.53)	0.03 (–0.91, 0.96)	0.96
Geriatric	0.48 (0.67)	0.47 (0.31)	0.01 (–0.60, 0.63)	0.96

Table S6. Within-group sex differences in the proportion of repetitive to varied transitions across age cohorts. Comparison of mean proportion of repetitive tetragrams and standard deviation (SD) between males and females within each group. Effect sizes were calculated using Cohen's *d* with Hedges' *g* bias correction for small sample sizes and 95% confidence intervals (CI). Positive values indicate higher male means; negative values indicate higher female means. *P*-values were adjusted using Bonferroni correction.

Proportion of repetitive to varied transitions (Overall Data)				
Group	N	Mean (SD)	Cohen's *d* vs. Control (95% CI)	*P*-value vs. Control
Control	19	0.43 ± 0.68	—	—
Acarbose	19	0.31 ± 0.28	–0.21 (–0.85, 0.43)	0.39
Rapamycin	21	0.61 ± 1.17	0.18 (–0.44, 0.80)	0.90
Phenylbutyrate	21	0.35 ± 0.51	–0.12 (–0.74, 0.50)	0.87
Combined	19	0.37 ± 0.38	–0.10 (–0.74, 0.50)	0.51
Proportion of repetitive to varied transitions (Female Data)				
Group	N	Mean (SD)	Cohen's *d* vs. Control (95% CI)	*P*-value vs. Control
Control	4	0.91 ± 1.27	—	—
Acarbose	8	0.46 ± 0.30	–0.56 (–1.78, 0.67)	0.93
Rapamycin	8	1.16 ± 1.79	0.14 (–1.07, 1.34)	0.93
Phenylbutyrate	11	0.55 ± 0.65	–0.41 (–1.56, 0.75)	0.90
Combined	9	0.40 ± 0.47	–0.61 (–1.82, 0.59)	0.64
Proportion of repetitive to varied transitions (Male Data)				
Group	N	Mean (SD)	Cohen's *d* vs. Control (95% CI)	*P*-value vs. Control
Control	15	0.30 ± 0.40	—	—
Acarbose	11	0.21 ± 0.21	–0.26 (–1.05, 0.52)	0.89
Rapamycin	13	0.27 ± 0.30	-0.08 (–0.82, 0.66)	0.92

Phenylbutyrate	10	0.14 ± 0.15	–0.47 (–1.28, 0.34)	0.80
Combined	10	0.34 ± 0.30	0.11 (–0.69, 0.91)	0.31

Table S7. Treatment-related differences in the proportion of repetitive to varied transitions in the Y-maze across all crickets and by sex. Mean proportion of repetitive tetragrams and standard deviation (SD) for each group. Effect sizes were calculated using Cohen's *d* with Hedges' *g* bias correction for small sample sizes and 95% confidence intervals (CI), using the control cohort as the reference group. Adjusted *P*-values reflect comparisons against the control cohort. N = sample size per group.

Proportion of repetitive to varied transitions				
	Mean (SD)		*d* (95% CI)	Adj. *P*-Value
Group	Male	Female		
Control	0.30 (0.40)	0.91 (1.27)	–0.91 (–2.05, 0.24)	0.72
Acarbose	0.21 (0.21)	0.46 (0.30)	–0.97 (–1.93, 0.00)	0.18
Rapamycin	0.27 (0.30)	1.16 (1.79)	–0.77 (–1.68, 0.15)	0.72
Phenylbutyrate	0.14 (0.15)	0.55 (0.65)	–0.82 (–1.72, 0.07)	0.59
Cocktail	0.34 (0.30)	0.40 (0.47)	–0.15 (–1.05, 0.75)	0.94

Table S8. Within-group sex differences in the proportion of repetitive to varied transitions across treatment cohorts. Comparison of mean proportion of repetitive tetragrams and standard deviation (SD) between males and females within each group. Effect sizes were calculated using Cohen's *d* with Hedges' *g* bias correction for small sample sizes and 95% confidence intervals (CI). Positive values indicate higher male means; negative values indicate higher female means. *P*-values were adjusted using Bonferroni correction.

Entropy (Overall Data)				
Group	N	Mean (SD)	Cohen's *d* vs. Control (95% CI)	*P*-value vs. Control
Juvenile	20	3.13 (0.75)	-0.02 (-0.56, 0.51)	0.94
Adult	21	3.81 (0.50)	1.04 (0.48, 1.60)	<0.0001
Mid-Age	19	2.66 (1.07)	-0.57 (-1.13, -0.02)	0.26
Geriatric	44	3.14 (0.69)	Reference	Reference
Entropy (Male Data)				
Group	N	Mean (SD)	Cohen's *d* vs. Control (95% CI)	*P*-value vs. Control
Juvenile	11	3.13 (0.76)	-0.16 (-0.89, 0.58)	>0.99
Adult	12	3.80 (0.29)	0.82 (0.09, 1.54)	0.015
Mid-Age	12	2.45 (1.00)	-0.92 (-1.65, -0.19)	0.081
Geriatric	23	3.25 (0.75)	Reference	Reference
Entropy (Female Data)				
Group	N	Mean (SD)	Cohen's *d* vs. Control (95% CI)	*P*-value vs. Control
Juvenile	9	3.44 (0.47)	0.88 (0.03, 1.72)	0.123
Adult	9	3.83 (0.70)	1.40 (0.49, 2.31)	0.006

Mid-Age	7	2.90 (1.17)	-0.09 (-1.09, 0.91)	>0.99
Geriatric	18	2.98 (0.55)	Reference	Reference

Table S9. Within-group sex differences in entropy values across age cohorts. Comparison of mean proportion of repetitive tetragrams and standard deviation (SD) between males and females within each group. Effect sizes were calculated using Cohen’s *d* with Hedges’ *g* bias correction for small sample sizes and 95% confidence intervals (CI). Positive values indicate higher male means; negative values indicate higher female means. *P*-values were adjusted using Bonferroni correction.

Group	Mean (SD)		Cohen’s *d* (95% CI)	*P*-value
	Male	Female		
Juvenile	3.13 (0.76)	3.44 (0.47)	–0.47 (–1.28, 0.34)	0.25
Adult	3.80 (0.29)	3.83 (0.70)	–0.06 (–0.86, 0.74)	0.88
Mid-Age	2.45 (1.00)	2.90 (1.17)	–0.42 (–1.31, 0.47)	0.35
Geriatric	3.25 (0.75)	2.98 (0.55)	0.41 (–0.15, 0.97)	0.14

Table S10. Within-group sex differences in entropy values across age cohorts. Comparison of mean entropy values and standard deviation (SD) between males and females within each group. Effect sizes were calculated using Cohen’s *d* with Hedges’ *g* bias correction for small sample sizes and 95% confidence intervals (CI). Positive values indicate higher male means; negative values indicate higher female means. *P*-values were adjusted using Bonferroni correction.

Entropy (Overall Data)				
Group	N	Mean (SD)	Cohen’s *d* vs. Control (95% CI)	*P*-value vs. Control
Control	22	2.70 (1.24)	—	—
Acarbose	20	3.08 (0.94)	0.34 (-0.27, 0.95)	0.35
Rapamycin	22	2.69 (1.17)	-0.01 (-0.61, 0.58)	0.83
Phenylbutyrate	21	2.97 (0.79)	0.25 (-0.35, 0.85)	0.69
Combined	20	2.69 (0.86)	-0.01 (-0.62, 0.59)	0.43
Entropy (Female Data)				
Group	N	Mean (SD)	Cohen’s *d* vs. Control (95% CI)	*P*-value vs. Control
Control	7	1.63 (1.64)	—	—
Acarbose	9	2.77 (1.26)	0.75 (-0.28, 1.77)	0.046
Rapamycin	9	1.83 (1.23)	0.13 (-0.86, 1.12)	>0.99
Phenylbutyrate	11	2.78 (0.69)	0.95 (-0.05, 1.96)	0.033
Combined	10	2.49 (0.94)	0.64 (-0.35, 1.63)	0.33
Entropy (Male Data)				
Group	N	Mean (SD)	Cohen’s *d* vs. Control (95% CI)	*P*-value vs. Control
Control	15	3.20 (0.54)	—	—
Acarbose	11	3.34 (0.52)	0.24 (-0.54, 1.03)	0.60
Rapamycin	13	3.28 (0.66)	0.13 (-0.62, 0.87)	0.66
Phenylbutyrate	10	3.18 (0.88)	-0.04 (-0.84, 0.76)	0.52
Combined	10	2.90 (0.77)	-0.46 (-1.27, 0.35)	0.37

Table S11. Treatment-related differences in entropy values across all crickets and by sex. Mean proportion of entropy values and standard deviation (SD) for each group. Effect sizes were calculated using Cohen’s *d* with Hedges’ *g* bias correction for small sample sizes and 95%

confidence intervals (CI), using the control cohort as the reference group. Adjusted *P*-values reflect comparisons against the control cohort. N = sample size per group.

Entropy				
	Mean (SD)		*d* (95% CI)	Adj. *P*-Value
Group	Male	Female		
Control	3.20 (0.54)	1.63 (1.64)	1.50 (0.49, 2.51)	0.0013
Acarbose	3.34 (0.52)	2.77 (1.26)	0.59 (–0.31, 1.49)	0.45
Rapamycin	3.28 (0.66)	1.83 (1.23)	1.51 (0.54, 2.47)	0.0019
Phenylbutyrate	3.18 (0.88)	2.78 (0.69)	0.49 (–0.38, 1.36)	0.32
Cocktail	2.90 (0.77)	2.49 (0.94)	0.46 (–0.43, 1.35)	0.41

Table S12. Within-group sex differences in entropy values across treatment cohorts. Comparison of mean entropy values and standard deviation (SD) between males and females within each group. Effect sizes were calculated using Cohen's *d* with Hedges' *g* bias correction for small sample sizes and 95% confidence intervals (CI). Positive values indicate higher male means; negative values indicate higher female means. *P*-values were adjusted using Bonferroni correction.

Appendix 5.

	Group [Mean (SD)]			Adult-Mid-Age		Adult-Geriatric		Mid-Age-Geriatric	
	Adult	Mid-Age	Geriatric	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Overall	N = 20	N = 20	N = 16	0.73 (0.09, 1.37)	**0.047**	0.98 (0.28, 1.67)	**0.019**	0.16 (-0.49, 0.82)	0.87
	63.75 (13.39)	53.13 (15.11)	50.78 (12.47)						
Female	N = 10	N = 10	N = 8	0.35 (-0.54, 1.23)	0.69	0.65 (-0.30, 1.60)	0.48	0.16 (-0.77, 1.10)	0.92
	57.50 (10.54)	52.50 (16.46)	50.00 (11.57)						
Male	N = 10	N = 10	N = 8	1.11 (0.17, 2.06)	**0.027**	1.28 (0.26, 2.30)	**0.017**	0.15 (-0.79, 1.08)	0.94
	70.00 (13.44)	53.75 (14.49)	51.56 (14.07)						

Table S1. Group means and effect sizes for scent preference test across age groups. Mean values with standard deviations (SD) are reported for percentage of vanilla arm entries in adult, mid-age, and geriatric crickets (N = number of individuals per group). Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Adults served as the reference group for adult-mid-age and adult-geriatric comparisons, while mid-age served as the reference group for mid-age-geriatric comparisons. Adjusted *P*-values were calculated using Tukey's Honestly Significant Difference (HSD) post-hoc test.

Percentage of Vanilla Arm Entries (%)							
Adult (N_{Female} = 10, N_{Male} = 10)				Mid-Age (N_{Female} = 10, N_{Male} = 10)			
Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*
Female	Male			Female	Male		

57.5 (10.54)	70.0 (13.44)	-0.99 (-1.92, -0.06)	0.13	52.5 (16.46)	53.75 (14.49)	-0.08 (-0.95, 0.80)	>0.99

Geriatric (N_{Female} = 8, N_{Male} = 8)			
Mean (SD)		*d* (95% CI)	*P*
Female	Male		
50.0 (11.57)	51.56 (14.07)	-0.11 (-1.10, 0.87)	0.99

Table S2. Group means and effect sizes for scent preference test comparing sexes within each age group. Mean values with standard deviations (SD) are reported for percentage of vanilla arm entries in adult, mid-age, and geriatric crickets (N = number of individuals per group). Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Females served as the reference group for all comparisons. Adjusted *P*-values were calculated using Bonferroni's multiple comparisons post-hoc test.

Percentage of Vanilla Arm Entries (%)					
	Mean (SD)				
	Control	Acarbose	Rapamycin	Phenylbutyrate	Combined
Overall	N = 19	N = 20	N = 20	N = 20	N = 20
	43.42 (13.42)	63.13 (14.89)	68.13 (13.13)	60.00 (11.89)	56.25 (15.44)
Female	N = 5	N = 10	N = 9	N = 10	N = 9
	47.50 (18.54)	60.00 (15.37)	68.06 (11.02)	56.25 (10.62)	56.94 (18.87)
Male	N = 14	N = 10	N = 11	N = 10	N = 11
	41.96 (11.61)	66.25 (14.49)	68.18 (15.17)	63.75 (12.43)	55.68 (12.95)

Table S3. Group means for the scent preference test across treatment groups. Mean values with standard deviations (SD) are reported for each treadmill assay measure in control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets for overall and sex stratified groups (N = number of individuals per group).

	Control-Acarbose		Control-Rapamycin		Control-Phenylbutyrate		Control-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Overall	-1.36 (-2.06, -0.66)	**0.0008**	-1.82 (-2.57, -1.08)	**<0.0001**	-1.28 (-1.97, -0.59)	**0.0037**	-0.87 (-1.52, -0.21)	0.051
Female	-0.72 (-1.82, 0.39)	0.26	-1.38 (-2.58, -0.17)	**0.030**	-0.61 (-1.70, 0.49)	0.55	-0.47 (-1.58, 0.64)	0.50
Male	-1.82 (-2.78, -0.86)	**0.0002**	-1.91 (-2.86, -0.96)	**<0.0001**	-1.76 (-2.71, -0.81)	**0.0011**	-1.09 (-1.93, -0.24)	0.059

Table S4. Effect sizes for the scent preference test across treatment groups. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for percentage of vanilla arm entries in control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets overall and stratified by sex. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Controls served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

Percentage of Vanilla Arm Entries (%)											
Control				Acarbose				Rapamycin			
Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*
Female	Male			Female	Male			Female	Male		
47.5 (18.54)	41.96 (11.61)	0.39 (-0.64, 1.42)	>0.99	60.0 (15.37)	66.25 (14.49)	-0.40 (-1.29, 0.48)	>0.99	68.06 (11.02)	68.18 (15.17)	-0.01 (-0.89, 0.87)	>0.99
Phenylbutyrate				Combined							
Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*				
Female	Male			Female	Male						
56.25 (10.62)	63.75 (12.43)	-0.62 (-1.52, 0.28)	>0.99	56.94 (18.87)	55.68 (12.95)	0.08 (-0.80, 0.96)	>0.99				

Table S5. Group means and effect sizes for scent preference test comparing sexes within each treatment group. Mean values with standard deviations (SD) are reported for percentage of vanilla arm entries in control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Females served as the reference group for all comparisons. Adjusted *P*-values were calculated using Bonferroni's multiple comparisons post-hoc test.

	Adult-Control		Adult-Acarbose		Adult-Rapamycin	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Overall	1.49 (0.78, 2.19)	**0.0003**	0.04 (-0.58, 0.66)	>0.99	-0.32 (-0.95, 0.30)	>0.99
Female	0.70 (-0.41, 1.80)	0.55	-0.18 (-1.06, 0.70)	0.99	-0.94 (-1.88, 0.01)	0.33
Male	2.18 (1.16, 3.20)	**<0.0001**	0.26 (-0.62, 1.14)	0.96	0.12 (-0.74, 0.98)	>0.99
	Adult-Phenylbutyrate		Adult-Combined			
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value		
Overall	0.29 (-0.33, 0.91)	>0.99	0.29 (-0.33, 0.91)	>0.99		
Female	0.11 (-0.76, 0.99)	>0.99	0.11 (-0.76, 0.99)	>0.99		
Male	0.46 (-0.43, 1.35)	0.75	0.46 (-0.43, 1.35)	0.75		

Table S6. Effect sizes for scent preference test across treatment groups compared to adults. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for percentage of vanilla arm entries in adult, control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Adults served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

	Mid-Age-Control		Mid-Age-Acarbose		Mid-Age-Rapamycin	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Overall	0.66 (0.02, 1.31)	0.39	-0.65 (-1.29, -0.02)	0.22	-1.04 (-1.70, -0.38)	**0.010**
Female	0.27 (-0.80, 1.35)	0.96	-0.45 (-1.34, 0.44)	0.67	-1.05 (-2.01, -0.09)	0.079
Male	0.88 (0.04, 1.73)	0.17	-0.83 (-1.74, 0.09)	0.18	-0.93 (-1.83, -0.03)	0.086

	Mid-Age-Phenylbutyrate		Mid-Age-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Overall	-0.50 (-1.12, 0.13)	0.53	-0.50 (-1.12, 0.13)	0.53
Female	-0.26 (-1.14, 0.62)	0.97	-0.26 (-1.14, 0.62)	0.97
Male	-0.71 (-1.61, 0.19)	0.37	-0.71 (-1.61, 0.19)	0.37

Table S7. Effect sizes for scent preference test across treatment groups compared to mid-aged crickets. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for percentage of vanilla arm entries in adult, control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Mid-aged crickets served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

	Geriatric-Control		Geriatric-Acarbose		Geriatric-Rapamycin	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Overall	0.55 (-0.12, 1.23)	0.74	-0.87 (-1.56, -0.18)	0.15	-1.32 (-2.05, -0.60)	**0.0058**
Female	0.16 (-0.96, 1.28)	>0.99	-0.69 (-1.64, 0.27)	0.41	-1.52 (-2.60, -0.44)	**0.035**
Male	0.74 (-0.16, 1.63)	0.36	-0.98 (-1.96, 0.01)	0.10	-1.08 (-2.05, -0.10)	**0.043**

	Geriatric-Phenylbutyrate		Geriatric-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Overall	-0.74 (-1.42, -0.06)	0.34	-0.74 (-1.42, -0.06)	0.34
Female	-0.54 (-1.49, 0.41)	0.80	-0.54 (-1.49, 0.41)	0.80
Male	-0.88 (-1.85, 0.09)	0.21	-0.88 (-1.85, 0.09)	0.21

Table S8. Effect sizes for scent preference test across treatment groups compared to a historical geriatric cohort. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for percentage of vanilla arm entries in adult, control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). The historical geriatric cohort served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

	Pooled Control-Acarbose		Pooled Control-Rapamycin	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Overall	-1.18 (-1.77, -0.58)	**0.0015**	-1.61 (-2.24, -0.99)	**<0.0001**
Female	-0.74 (-1.52, 0.03)	0.20	-1.45 (-2.31, -0.58)	**0.0077**
Male	-1.38 (-2.15, -0.60)	**0.0006**	-1.49 (-2.26, -0.73)	**<0.0001**
	Pooled Control-Phenylbutyrate		Pooled Control-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Overall	-1.03 (-1.62, -0.45)	**0.0070**	-1.03 (-1.62, -0.45)	**0.0070**
Female	-0.54 (-1.30, 0.23)	0.57	-0.54 (-1.30, 0.23)	0.57
Male	-1.24 (-2.01, -0.48)	**0.0030**	-1.24 (-2.01, -0.48)	**0.0030**

Table S9. Effect sizes for scent preference test across treatment groups compared to pooled controls. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for percentage of vanilla arm entries in adult, control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Pooled controls served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

Appendix 6.

	Group [Mean (SD)]			Juvenile-Adult		Juvenile-Geriatric		Adult-Geriatric	
	Juvenile (N = 30)	Adult (N = 30)	Geriatric (N = 45)	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion									
Total Distance (cm)	4405 (1364)	2167 (944.7)	2057 (941.1)	1.88 (1.27, 2.49)	**<0.0001**	2.06 (1.49, 2.63)	**<0.0001**	0.12 (-0.35, 0.58)	0.90
Average Speed (cm/s)	14.44 (4.38)	7.17 (3.08)	6.67 (3.08)	1.90 (1.29, 2.50)	**<0.0001**	2.11 (1.53, 2.68)	**<0.0001**	0.16 (-0.30, 0.62)	0.82
Average Walking Speed (cm/s)	4.81 (1.69)	1.98 (0.87)	2.05 (0.96)	2.17 (1.53, 2.81)	**<0.0001**	2.10 (1.53, 2.67)	**<0.0001**	-0.07 (-0.54, 0.39)	0.80
Average Running Speed (cm/s)	33.77 (8.63)	19.92 (12.06)	18.99 (7.77)	1.30 (0.75, 1.86)	**<0.0001**	1.80 (1.26, 2.35)	**<0.0001**	0.09 (-0.37, 0.56)	0.91
Walking/Running Distance	1.93 (0.31)	2.72 (1.16)	3.40 (1.51)	-0.92 (-1.45,-0.39)	**0.03**	-1.22 (-1.73, -0.72)	**<0.0001**	-0.49 (-0.96, -0.02)	**0.04**
Walking/Running Time	6.86 (2.39)	10.29 (6.07)	15.37 (9.01)	-0.73 (-1.26,-0.21)	0.13	-1.18 (-1.68, -0.68)	**<0.0001**	-0.64 (-1.10, -0.16)	**0.006**
Measures of Exploration									

Central/Peripheral Distance	0.87 (0.80)	1.04 (1.36)	0.24 (0.22)	-0.15 (-0.66, 0.36)	0.72	1.17 (0.67, 1.67)	**0.007**	0.91 (0.42, 1.39)	**0.0004**
Central/Peripheral Time	0.38 (0.35)	0.22 (0.22)	0.12 (0.15)	0.54 (0.03, 1.06)	**0.03**	1.03 (0.54, 1.52)	**<0.0001**	0.55 (0.08, 1.02)	0.23
Central/Peripheral Speed	2.33 (1.04)	3.74 (2.16)	2.61 (1.23)	-0.82 (-1.35,-0.29)	**0.0013**	-0.24 (-0.70, 0.22)	0.71	0.67 (0.20, 1.15)	**0.006**
Total Freezing Counts	2846 (936)	2518 (1230)	2012 (1233)	0.30 (-0.21, 0.81)	0.52	0.73 (0.26, 1.21)	**0.008**	0.41 (-0.06, 0.87)	0.16
Central Freezing Counts	1177 (1069)	995.1 (1160)	386.2 (1114)	0.16 (-0.35, 0.67)	0.80	0.71 (0.24, 1.19)	**0.009**	0.54 (0.06, 1.00)	0.06
Peripheral Freezing Counts	1669 (589)	1523 (593)	1626 (804.4)	0.24 (-0.26, 0.75)	0.69	0.06 (-0.40, 0.52)	0.96	-0.14 (-0.60, 0.32)	0.80

Table S1. Group means and effect sizes for locomotion and exploration measures across age groups. Mean values with standard deviations (SD) are reported for each locomotor and exploratory measure in juvenile, adult, and geriatric crickets (N = number of individuals per group). Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Juveniles served as the reference group for juvenile-adult and juvenile-geriatric comparisons, while adults served as the reference group for adult-geriatric comparisons. Adjusted *P*-values were calculated using Tukey's Honestly Significant Difference (HSD) post-hoc test.

	Juvenile (N_{Female} = 15, N_{Male} = 15)				Adult (N_{Female} = 15, N_{Male} = 15)				Geriatric (N_{Female} = 21, N_{Male} = 24)			
	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*
	Female	Male			Female	Male			Female	Male		
Measures of Locomotion												
Total Distance (cm)	4313 (1440)	4496 (1328)	-0.13 (-0.84, 0.59)	>0.99	2054 (1014)	2279 (891)	-0.23 (-0.95, 0.49)	>0.99	2023 (931)	2086 (969)	-0.07 (-0.65, 0.52)	>0.99
Average Speed (cm/s)	14.17 (4.57)	14.70 (4.34)	-0.11 (-0.83, 0.60)	>0.99	6.76 (3.27)	7.57 (2.93)	-0.25 (-0.97, 0.47)	>0.99	6.43 (2.99)	6.88 (3.21)	-0.14 (-0.72, 0.44)	>0.99
Average Walking Speed (cm/s)	4.69 (1.81)	4.94 (1.61)	-0.14 (-0.86, 0.57)	>0.99	1.76 (0.90)	2.20 (0.79)	-0.51 (-1.23, 0.22)	0.97	2.14 (1.15)	2.08 (0.91)	0.06 (-0.53, 0.64)	>0.99
Average Running Speed (cm/s)	35.28 (10.66)	32.27 (5.99)	0.34 (-0.38, 1.06)	>0.99	19.29 (13.95)	20.54 (10.29)	-0.10 (-0.82, 0.62)	>0.99	18.26 (8.17)	19.55 (7.78)	-0.16 (-0.75, 0.43)	>0.99
Walking/ Running Distance	1.94 (0.35)	1.93 (0.27)	0.02 (-0.69, 0.74)	>0.99	2.48 (0.82)	2.96 (1.41)	-0.41 (-1.13, 0.32)	0.80	3.14 (1.40)	3.63 (1.59)	-0.32 (-0.91, 0.27)	0.51
Walking/ Running Time	7.40 (2.56)	6.32 (2.16)	0.44 (-0.28, 1.17)	>0.99	9.26 (4.97)	11.33 (7.02)	-0.33 (-1.05, 0.39)	>0.99	14.32 (9.60)	16.29 (8.55)	-0.21 (-0.80, 0.37)	>0.99
Measures of Exploration												
Central/ Peripheral Distance	0.89 (0.96)	0.86 (0.64)	0.03 (-0.69, 0.74)	>0.99	0.97 (1.13)	1.12 (1.59)	-0.11 (-0.83, 0.61)	>0.99	0.25 (0.26)	0.24 (0.18)	0.02 (-0.57, 0.60)	>0.99
Central/ Peripheral Time	0.34 (0.38)	0.42 (0.33)	-0.19 (-0.91, 0.52)	>0.99	0.20 (0.18)	0.23 (0.25)	-0.15 (-0.86, 0.57)	>0.99	0.13 (0.20)	0.12 (0.09)	0.08 (-0.51, 0.66)	>0.99
Central/ Peripheral Speed	2.45 (1.23)	2.21 (0.82)	0.23 (-0.50, 0.94)	>0.99	3.89 (2.24)	3.59 (2.15)	0.13 (-0.58, 0.85)	>0.99	2.73 (1.21)	2.36 (1.01)	0.33 (-0.26, 0.92)	>0.99
Total Freezing Counts	2731 (735)	2960 (1116)	-0.24 (-0.95, 0.48)	>0.99	2557 (1223)	2479 (1280)	0.06 (-0.66, 0.78)	>0.99	2386 (1614)	1685 (633)	0.58 (-0.02, 1.17)	0.13
Central Freezing Counts	1060 (946)	1293 (1201)	-0.21 (-0.93, 0.51)	>0.99	1027 (1073)	964 (1278)	0.05 (-0.66, 0.77)	>0.99	623 (1612)	179 (133)	0.40 (-0.20, 0.99)	0.56
Peripheral Freezing Counts	1671 (459)	1668 (712)	0.01 (-0.71, 0.72)	>0.99	1530 (589)	1515 (618)	0.02 (-0.69, 0.74)	>0.99	1763 (1007)	1506 (569)	0.32 (-0.27, 0.90)	0.66

Table S2. Group means and effect sizes for locomotion and exploration measures comparing sexes within each age group. Mean values with standard deviations (SD) are reported for each locomotor and exploratory measure in juvenile, adult, and geriatric crickets (N = number of individuals per group). Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Females served as the reference group for all comparisons. Adjusted *P*-values were calculated using Bonferroni's multiple comparisons post-hoc test.

Female	Group [Mean (SD)]			Juvenile-Adult		Juvenile-Geriatric		Adult-Geriatric	
	Juvenile (N = 15)	Adult (N = 15)	Geriatric (N = 21)	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion									
Total Distance (cm)	4313 (1440)	2054 (1014)	2023 (931)	1.76 (0.92, 2.61)	**<0.0001**	1.92 (1.12, 2.71)	**<0.0001**	0.03 (-0.63, 0.69)	>0.99
Average Speed (cm/s)	14.17 (4.57)	6.76 (3.27)	6.43 (2.99)	1.81 (0.96, 2.66)	**<0.0001**	2.03 (1.22, 2.85)	**<0.0001**	0.10 (-0.56, 0.77)	0.96
Average Walking Speed (cm/s)	4.69 (1.81)	1.76 (0.90)	2.14 (1.15)	1.99 (1.12, 2.87	**<0.0001**	1.71 (0.94, 2.48)	**<0.0001**	-0.35 (-1.02, 0.32)	0.63
Average Running Speed (cm/s)	35.28 (10.66)	19.29 (13.95)	18.26 (8.17)	1.25 (0.47, 2.04)	**<0.0001**	1.79 (1.01, 2.58)	**<0.0001**	0.09 (-0.57, 0.76)	0.95
Walking/Running Distance	1.94 (0.35)	2.48 (0.82)	3.14 (1.40)	-0.83 (-1.58,-0.09)	0.42	-1.07 (-1.78, -0.36)	**0.009**	-0.54 (-1.21, 0.13)	0.22
Walking/Running Time	7.40 (2.56)	9.26 (4.97)	14.32 (9.60)	-0.46 (-1.18, 0.27)	0.74	-0.90 (-1.59, -0.20)	**0.01**	-0.62 (-1.29, 0.06)	0.08
Measures of Exploration									
Central/Peripheral Distance	0.89 (0.96)	0.97 (1.13)	0.25 (0.26)	-0.07 (-0.79, 0.64)	0.97	0.97 (0.27, 1.67)	0.08	0.94 (0.24, 1.63)	**0.04**
Central/Peripheral Time	0.34 (0.38)	0.20 (0.18)	0.13 (0.20)	0.46 (-0.27, 1.18)	0.24	0.71 (0.03, 1.40)	**0.03**	0.36 (-0.31, 1.02)	0.67
Central/Peripheral Speed	2.45 (1.23)	3.89 (2.24)	2.73 (1.21)	-0.78 (-1.52,-0.03)	**0.03**	-0.22 (-0.89, 0.44)	>0.99	0.66 (-0.02, 1.34)	0.07
Total Freezing Counts	2731 (735)	2557 (1223)	2386 (1614)	0.17 (-0.55, 0.88)	0.91	0.25 (-0.41, 0.92)	0.65	0.11 (-0.55, 0.78)	0.90
Central Freezing Counts	1060 (946)	1027 (1073)	623 (1612)	0.03 (-0.68, 0.75)	>0.99	0.31 (-0.36, 0.98)	0.48	0.28 (-0.39, 0.94)	0.54
Peripheral Freezing Counts	1671 (459)	1530 (589)	1763 (1007)	0.26 (-0.46, 0.98)	0.84	-0.11 (-0.77, 0.55)	0.92	-0.26 (-0.93, 0.40)	0.58
Male	Group [Mean (SD)]			Juvenile-Adult		Juvenile-Geriatric		Adult-Geriatric	
	Juvenile (N = 15)	Adult (N = 15)	Geriatric (N = 24)	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion									
Total Distance (cm)	4496 (1328)	2279 (891)	2086 (969)	1.91 (1.04, 2.77)	**<0.0001**	2.11 (1.31, 2.91)	**<0.0001**	0.20 (-0.45, 0.85)	0.85
Average Speed (cm/s)	14.70 (4.34)	7.57 (2.93)	6.88 (3.21)	1.87 (1.01, 2.73)	**<0.0001**	2.08 (1.29, 2.88)	**<0.0001**	0.22 (-0.43, 0.86)	0.82
Average Walking Speed (cm/s)	4.94 (1.61)	2.20 (0.79)	2.08 (0.91)	2.10 (1.21, 2.99)	**<0.0001**	2.29 (1.47, 3.11)	**<0.0001**	0.14 (-0.51, 0.78)	0.95
Average Running Speed (cm/s)	32.27 (5.99)	20.54 (10.29)	19.55 (7.78)	1.36 (0.56, 2.15)	**0.0031**	1.74 (0.99, 2.49)	**0.0003**	0.11 (-0.54, 0.76)	0.95

Walking/Running Distance	1.93 (0.27)	2.96 (1.41)	3.63 (1.59)	-0.99 (-1.75,-0.23)	**0.048**	-1.32 (-2.03, -0.61)	**<0.0001**	-0.43 (-1.08, 0.22)	0.20
Walking/Running Time	6.32 (2.16)	11.33 (7.02)	16.29 (8.55)	-0.94 (-1.69,-0.18)	0.12	-1.42 (-2.14, -0.70)	**<0.0001**	-0.61 (-1.27, 0.05)	0.08
Measures of Exploration									
Central/Peripheral Distance	0.86 (0.64)	1.12 (1.59)	0.24 (0.18)	-0.21 (-0.93, 0.51)	0.69	1.45 (0.73, 2.17)	0.08	0.87 (0.20, 1.55)	**0.008**
Central/Peripheral Time	0.42 (0.33)	0.23 (0.25)	0.12 (0.09)	0.63 (-0.10, 1.36)	0.10	1.37 (0.65, 2.08)	**0.001**	0.64 (-0.02, 1.30)	0.33
Central/Peripheral Speed	2.21 (0.82)	3.59 (2.15)	2.36 (1.01)	-0.83 (-1.57,-0.08)	**0.04**	-0.16 (-0.80, 0.49)	>0.99	0.78 (0.11, 1.45)	**0.04**
Total Freezing Counts	2960 (1116)	2479 (1280)	1685 (633)	0.39 (-0.33, 1.11)	0.49	1.47 (0.75, 2.19)	**0.003**	0.83 (0.16, 1.51)	0.09
Central Freezing Counts	1293 (1201)	964 (1278)	179 (133)	0.26 (-0.46, 0.98)	0.70	1.46 (0.74, 2.18)	**0.009**	0.97 (0.29, 1.65)	0.09
Peripheral Freezing Counts	1668 (712)	1515 (618)	1506 (569)	0.22 (-0.49, 0.94)	0.82	0.25 (-0.39, 0.90)	0.76	0.01 (-0.63, 0.66)	>0.99

Table S3. Group means and effect sizes for locomotion and exploration measures across age groups stratified by sex. Mean values with standard deviations (SD) are reported for each locomotor and exploratory measure in juvenile, adult, and geriatric crickets (N = number of individuals per group). Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Juveniles served as the reference group for juvenile-adult and juvenile-geriatric comparisons, while adults served as the reference group for adult-geriatric comparisons. Adjusted *P*-values were calculated using Tukey's Honestly Significant Difference (HSD) post-hoc test.

	Mean (SD)				
	Control (N = 19)	Acarbose (N = 20)	Rapamycin (N = 20)	Phenylbutyrate (N = 20)	Combined (N = 20)
Measures of Locomotion					
Total Distance (cm)	2938 (885)	2542 (925)	3340 (1283)	2245 (705)	2523 (1131)
Average Speed (cm/s)	9.34 (2.83)	8.38 (3.05)	11.02 (4.19)	7.39 (2.25)	8.25 (3.77)
Average Walking Speed (cm/s)	2.83 (1.04)	2.40 (0.82)	3.00 (1.26)	2.09 (0.50)	2.39 (1.25)
Average Running Speed (cm/s)	27.9 (5.9)	22.7 (5.2)	29.2 (6.7)	23.1 (5.3)	22.2 (7.8)
Walking/Running Distance	2.19 (0.64)	2.96 (1.25)	2.29 (0.73)	2.69 (0.90)	2.62 (0.95)
Walking/Running Time	10.8 (4.6)	13.8 (8.1)	10.1 (5.0)	14.2 (8.5)	11.3 (6.1)
Measures of Exploration					
Central/Peripheral Distance	0.51 (0.25)	0.26 (0.40)	0.79 (0.64)	0.58 (0.62)	0.42 (0.23)
Central/Peripheral Time	0.19 (0.14)	0.26 (0.40)	0.38 (0.36)	0.18 (0.16)	0.25 (0.31)
Central/Peripheral Speed	3.13 (0.99)	2.84 (1.26)	2.28 (0.53)	3.30 (1.15)	2.27 (0.72)
Total Freezing Counts	2302 (755)	2985 (1239)	3691 (984)	2875 (721)	2868 (841)
Central Freezing Counts	412.9 (304.0)	401.2 (748.1)	1526 (1109)	547.3 (412.7)	831.5 (658.3)
Peripheral Freezing Counts	1889 (722)	2584 (1032)	2165 (776)	2328 (754)	2036 (426)

Table S4. Group means for locomotion and exploration measures across treatment groups. Mean values with standard deviations (SD) are reported for each locomotor and exploratory measure in control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets (N = number of individuals per group).

	Control-Acarbose		Control-Rapamycin		Control-Phenylbutyrate		Control-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion								
Total Distance (cm)	0.43 (-0.21, 1.06)	0.55	-0.36 (-0.99, 0.28)	0.53	0.85 (0.20, 1.51)	0.11	0.40 (-0.24, 1.03)	0.51
Average Speed (cm/s)	0.32 (-0.31, 0.95)	0.77	-0.46 (-1.09, 0.18)	0.31	0.75 (0.10, 1.40)	0.20	0.32 (-0.31, 0.95)	0.69
Average Walking Speed (cm/s)	0.45 (-0.18, 1.09)	0.48	-0.14 (-0.77, 0.48)	0.96	0.90 (0.24, 1.55)	0.08	0.37 (-0.26, 1.01)	0.45
Average Running Speed (cm/s)	0.92 (0.26, 1.58)	**0.04**	-0.20 (-0.83, 0.43)	0.90	0.84 (0.18, 1.49)	0.06	0.80 (0.15, 1.46)	**0.02**
Walking/Running Distance	-0.75 (-1.40, -0.10)	**0.04**	-0.14 (-0.77, 0.49)	0.99	-0.62 (-1.27, 0.02)	0.26	-0.52 (-1.16, 0.12)	0.40
Walking/Running Time	-0.44 (-1.08, 0.19)	0.43	0.14 (-0.49, 0.77)	0.99	-0.48 (-1.12, 0.15)	0.32	-0.09 (-0.72, 0.54)	>0.99
Measures of Exploration								
Central/Peripheral Distance	0.73 (0.08, 1.38)	0.27	-0.56 (-1.20, 0.08)	0.18	-0.14 (-0.77, 0.49)	0.96	0.37 (-0.27, 1.00)	0.93
Central/Peripheral Time	-0.23 (-0.86, 0.40)	0.88	-0.67 (-1.32, -0.03)	0.15	0.07 (-0.56, 0.69)	>0.99	-0.24 (-0.87, 0.39)	0.93
Central/Peripheral Speed	0.25 (-0.38, 0.88)	0.75	1.06 (0.39, 1.73)	**0.03**	-0.15 (-0.78, 0.47)	0.95	0.98 (0.31, 1.64)	**0.02**
Total Freezing Counts	-0.65 (-1.29, 0.00)	0.08	-1.55 (-2.26, -0.83)	**<0.0001**	-0.76 (-1.41, -0.11)	0.17	-0.69 (-1.34, -0.05)	0.18
Central Freezing Counts	0.02 (-0.61, 0.65)	>0.99	-1.33 (-2.02, -0.63)	**<0.0001**	-0.36 (-0.99, 0.27)	0.94	-0.79 (-1.44, -0.14)	0.20
Peripheral Freezing Counts	-0.76 (-1.41, -0.11)	**0.02**	-0.36 (-0.99, 0.27)	0.62	-0.58 (-1.22, 0.06)	0.23	-0.24 (-0.87, 0.39)	0.93

Table S5. Effect sizes for locomotion and exploration measures across treatment groups. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for each locomotor and exploratory measure in control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Controls served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

Female	Mean (SD)				
	Control (N = 9)	Acarbose (N = 10)	Rapamycin (N = 10)	Phenylbutyrate (N = 10)	Combined (N = 10)
Measures of Locomotion					
Total Distance (cm)	2709 (874.9)	2400 (908.8)	2990 (948.7)	2393 (940.5)	2474 (1143)
Average Speed (cm/s)	8.62 (2.72)	7.93 (3.05)	9.91 (3.15)	7.84 (3.00)	8.02 (3.81)
Average Walking Speed (cm/s)	2.43 (0.89)	2.23 (0.77)	2.56 (0.66)	2.10 (0.61)	2.40 (1.46)
Average Running Speed (cm/s)	27.3 (7.65)	21.18 (5.20)	27.1 (6.61)	24.1 (5.30)	22.3 (5.73)

Walking/Running Distance	2.22 (0.82)	2.98 (1.27)	2.23 (0.72)	2.57 (0.93)	3.00 (1.09)
Walking/Running Time	11.7 (5.44)	14.28 (9.34)	9.70 (4.37)	15.0 (11.23)	13.3 (5.78)
Central/Peripheral Distance	0.47 (0.21)	0.14 (0.13)	0.62 (0.49)	0.86 (0.77)	0.34 (0.16)
Central/Peripheral Time	0.16 (0.12)	0.06 (0.07)	0.27 (0.24)	0.24 (0.20)	0.16 (0.14)
Central/Peripheral Speed	3.42 (1.03)	2.85 (1.55)	2.40 (0.60)	3.66 (1.00)	2.42 (0.56)
Total Freezing Counts	2020 (467.6)	2699 (1199)	3670 (719.7)	2615 (576.9)	2759 (869.8)
Central Freezing Counts	346 (254.8)	154 (161.9)	1298 (926.0)	591 (458.1)	632 (651.38)
Peripheral Freezing Counts	1674 (452.3)	2546 (1128)	2372 (742.8)	2024 (618.1)	2128 (382.6)
Male	Mean (SD)				
	Control (N = 10)	Acarbose (N = 10)	Rapamycin (N = 10)	Phenylbutyrate (N = 10)	Combined (N = 10)
Measures of Locomotion					
Total Distance (cm)	3144 (887.7)	2685 (966.8)	3689 (1518)	2097 (338.6)	2572 (1180)
Average Speed (cm/s)	9.98 (2.91)	8.83 (3.13)	12.1 (4.93)	6.95 (1.12)	8.49 (3.92)
Average Walking Speed (cm/s)	3.20 (1.07)	2.57 (0.86)	3.44 (1.58)	2.09 (0.40)	2.38 (1.08)
Average Running Speed (cm/s)	28.4 (4.12)	24.29 (5.07)	31.4 (6.41)	22.1 (5.45)	22.02 (9.70)
Walking/Running Distance	2.16 (0.47)	2.93 (1.29)	2.34 (0.78)	2.82 (0.89)	2.24 (0.64)
Walking/Running Time	10.0 (3.68)	13.33 (7.09)	10.4 (5.75)	13.4 (4.85)	9.24 (5.92)
Central/Peripheral Distance	0.55 (0.28)	0.38 (0.54)	0.97 (0.74)	0.31 (0.20)	0.51 (0.26)
Central/Peripheral Time	0.22 (0.15)	0.14 (0.21)	0.49 (0.43)	0.11 (0.08)	0.34 (0.41)
Central/Peripheral Speed	2.87 (0.93)	2.82 (0.98)	2.17 (0.46)	2.93 (1.23)	2.13 (0.85)
Total Freezing Counts	2555 (891.3)	3271 (1274)	3711 (1235)	3136 (782.5)	2976 (843.1)
Central Freezing Counts	473 (344.4)	649 (1009)	1753 (1274)	503 (381.4)	1031 (633.9)
Peripheral Freezing Counts	2082 (879.2)	2622 (985.7)	1958 (789.2)	2633 (782.6)	1945 (466.3)

Table S6. Group means for locomotion and exploration measures across treatment groups stratified by sex. Mean values with standard deviations (SD) are reported for each locomotor and exploratory measure in control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated females and males (N = number of individuals per group).

Female	Control-Acarbose		Control-Rapamycin		Control-Phenylbutyrate		Control-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion								
Total Distance (cm)	0.33 (−0.58, 1.24)	0.90	-0.29 (-1.20, 0.61)	0.93	0.33 (-0.58, 1.24)	0.90	0.22 (-0.68, 1.12)	0.96
Average Speed (cm/s)	0.23 (−0.68, 1.13)	0.97	-0.42 (-1.33, 0.49)	0.80	0.26 (-0.64, 1.16)	0.96	0.17 (-0.73, 1.07)	0.98
Average Walking Speed (cm/s)	0.23 (−0.67, 1.13)	0.98	-0.16 (-1.06, 0.74)	0.99	0.42 (-0.49, 1.33)	0.88	0.02 (-0.88, 0.92)	>0.99
Average Running Speed (cm/s)	0.90 (−0.04, 1.85)	0.11	0.03 (-0.87, 0.93)	>0.99	0.47 (-0.44, 1.38)	0.63	0.71 (-0.22, 1.64)	0.25
Walking/Running Distance	−0.67 (−1.60, 0.25)	0.22	-0.01 (-0.91, 0.89)	>0.99	-0.38 (-1.29, 0.53)	0.83	-0.77 (-1.70, 0.17)	0.21
Walking/Running Time	−0.32 (−1.22, 0.59)	0.81	0.39 (-0.52, 1.30)	0.91	-0.35 (-1.26, 0.56)	0.65	-0.27 (-1.18, 0.63)	0.96

Measures of Exploration								
Central/Peripheral Distance	1.83 (0.76, 2.90)	0.29	-0.37 (-1.28, 0.54)	0.88	-0.64 (-1.57, 0.28)	0.18	0.67 (-0.26, 1.60)	0.90
Central/Peripheral Time	0.99 (0.03, 1.94)	0.77	-0.54 (-1.46, 0.37)	0.69	-0.46 (-1.37, 0.46)	0.89	0.00 (-0.90, 0.90)	>0.99
Central/Peripheral Speed	0.41 (−0.50, 1.32)	0.52	1.17 (0.20, 2.15)	0.08	-0.23 (-1.13, 0.68)	0.95	1.17 (0.20, 2.15)	0.09
Total Freezing Counts	−0.70 (−1.63, 0.23)	0.32	-2.57 (-3.78, -1.35)	**0.0008**	-1.08 (-2.04, -0.11)	0.43	-0.99 (-1.95, -0.04)	0.25
Central Freezing Counts	0.87 (−0.07, 1.81)	0.93	-1.31 (-2.30, -0.31)	**0.014**	-0.62 (-1.54, 0.30)	0.86	-0.54 (-1.46, 0.38)	0.78
Peripheral Freezing Counts	−0.95 (−1.90, 0.00)	**0.05**	-1.07 (-2.03, -0.11)	0.15	-0.61 (-1.53, 0.31)	0.70	-1.04 (-2.00, -0.08)	0.50
Male	Control-Acarbose		Control-Rapamycin		Control-Phenylbutyrate		Control-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion								
Total Distance (cm)	0.47 (−0.42, 1.36)	0.70	-0.42 (-1.31, 0.47)	0.57	1.49 (0.50, 2.48)	0.08	0.52 (-0.37, 1.42)	0.53
Average Speed (cm/s)	0.36 (−0.52, 1.25)	0.85	-0.50 (-1.39, 0.39)	0.40	1.32 (0.35, 2.28)	0.14	0.41 (-0.47, 1.30)	0.71
Average Walking Speed (cm/s)	0.62 (−0.28, 1.52)	0.44	-0.17 (-1.05, 0.71)	0.95	1.32 (0.35, 2.28)	0.05	0.73 (-0.17, 1.64)	0.21
Average Running Speed (cm/s)	0.85 (−0.06, 1.77)	0.39	-0.53 (-1.43, 0.36)	0.67	1.25 (0.29, 2.21)	0.09	0.82 (-0.09, 1.73)	0.08
Walking/Running Distance	−0.76 (−1.67, 0.15)	0.20	-0.27 (-1.15, 0.61)	0.98	-0.89 (-1.81, 0.03)	0.32	-0.14 (-1.01, 0.74)	>0.99
Walking/Running Time	−0.56 (−1.46, 0.33)	0.64	-0.08 (-0.96, 0.80)	>0.99	-0.76 (-1.66, 0.15)	0.63	0.15 (-0.73, 1.03)	>0.99
Measures of Exploration								
Central/Peripheral Distance	0.38 (−0.51, 1.26)	0.83	-0.72 (-1.62, 0.19)	0.11	0.94 (0.02, 1.87)	0.58	0.14 (-0.74, 1.02)	>0.99
Central/Peripheral Time	0.42 (−0.47, 1.31)	0.86	-0.80 (-1.71, 0.11)	**0.05**	0.88 (-0.04, 1.79)	0.72	-0.37 (-1.26, 0.51)	0.61
Central/Peripheral Speed	0.05 (−0.83, 0.93)	>0.99	0.91 (-0.01, 1.83)	0.30	-0.05 (-0.93, 0.82)	>0.99	0.80 (-0.12, 1.71)	0.26
Total Freezing Counts	−0.62 (−1.52, 0.27)	0.26	-1.03 (-1.96, -0.10)	**0.023**	-0.66 (-1.56, 0.24)	0.43	-0.46 (-1.35, 0.42)	0.70
Central Freezing Counts	−0.22 (−1.10, 0.66)	0.95	-1.31 (-2.28, -0.35)	**0.0004**	-0.08 (-0.96, 0.80)	>0.99	-1.05 (-1.98, -0.11)	0.23
Peripheral Freezing Counts	−0.55 (−1.45, 0.34)	0.32	0.14 (-0.74, 1.02)	0.99	-0.63 (-1.53, 0.26)	0.31	0.19 (-0.69, 1.06)	0.98

Table S7. Effect sizes for locomotion and exploration measures across treatment groups stratified by sex. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for each locomotor and exploratory measure in control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Controls served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

	Control				Acarbose				Rapamycin			
	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*
	Female	Male			Female	Male			Female	Male		
Measures of Locomotion												
Total Distance (cm)	2709 (874.9)	3144 (887.7)	-0.47 (-1.38, 0.44)	>0.99	2400 (908.8)	2685 (966.8)	-0.29 (-1.17, 0.59)	>0.99	2990 (948.7)	3689 (1518)	-0.53 (-1.42, 0.36)	0.63
Average Speed (cm/s)	8.62 (2.72)	9.98 (2.91)	-0.46 (-1.37, 0.45)	>0.99	7.93 (3.05)	8.83 (3.13)	-0.28 (-1.16, 0.60)	>0.99	9.91 (3.15)	12.1 (4.93)	-0.51 (-1.40, 0.38)	0.68
Average Walking Speed (cm/s)	2.43 (0.89)	3.20 (1.07)	-0.74 (-1.67, 0.19)	0.50	2.23 (0.77)	2.57 (0.86)	-0.40 (-1.28, 0.49)	>0.99	2.56 (0.66)	3.44 (1.58)	-0.70 (-1.60, 0.21)	0.27
Average Running Speed (cm/s)	27.3 (7.65)	28.4 (4.12)	-0.17 (-1.08, 0.73)	>0.99	21.18 (5.20)	24.29 (5.07)	-0.58 (-1.47, 0.31)	>0.99	27.1 (6.61)	31.4 (6.41)	-0.63 (-1.53, 0.27)	0.64
Walking/Running Distance	2.22 (0.82)	2.16 (0.47)	0.09 (-0.81, 0.99)	>0.99	2.98 (1.27)	2.93 (1.29)	0.04 (-0.84, 0.91)	>0.99	2.23 (0.72)	2.34 (0.78)	-0.14 (-1.02, 0.74)	>0.99
Walking/Running Time	11.7 (5.44)	10.0 (3.68)	0.35 (-0.55, 1.26)	>0.99	14.28 (9.34)	13.33 (7.09)	0.11 (-0.77, 0.99)	>0.99	9.70 (4.37)	10.4 (5.75)	-0.13 (-1.01, 0.75)	>0.99
Measures of Exploration												
Central/Peripheral Distance	0.47 (0.21)	0.55 (0.28)	-0.31 (-1.21, 0.60)	>0.99	0.14 (0.13)	0.38 (0.54)	-0.59 (-1.48, 0.31)	>0.99	0.62 (0.49)	0.97 (0.74)	-0.53 (-1.43, 0.36)	0.40
Central/Peripheral Time	0.16 (0.12)	0.22 (0.15)	-0.42 (-1.33, 0.49)	>0.99	0.06 (0.07)	0.14 (0.21)	-0.49 (-1.38, 0.40)	>0.99	0.27 (0.24)	0.49 (0.43)	-0.61 (-1.50, 0.29)	0.25
Central/Peripheral Speed	3.42 (1.03)	2.87 (0.93)	0.54 (-0.38, 1.45)	>0.99	2.85 (1.55)	2.82 (0.98)	0.02 (-0.85, 0.90)	>0.99	2.40 (0.60)	2.17 (0.46)	0.41 (-0.47, 1.30)	>0.99
Total Freezing Counts	2020 (467.6)	2555 (891.3)	-0.71 (-1.63, 0.22)	0.86	2699 (1199)	3271 (1274)	-0.44 (-1.33, 0.44)	>0.99	3670 (719.7)	3711 (1235)	-0.04 (-0.92, 0.84)	>0.99
Central Freezing Counts	346 (254.8)	473 (344.4)	-0.40 (-1.31, 0.51)	>0.99	154 (161.9)	649 (1009)	-0.66 (-1.56, 0.24)	0.59	1298 (926.0)	1753 (1274)	-0.39 (-1.28, 0.49)	0.76
Peripheral Freezing Counts	1674 (452.3)	2082 (879.2)	-0.55 (-1.47, 0.37)	>0.99	2546 (1128)	2622 (985.7)	-0.07 (-0.95, 0.81)	>0.99	2372 (742.8)	1958 (789.2)	0.52 (-0.37, 1.41)	>0.99

	Phenylbutyrate				Combined			
	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*
	Female	Male			Female	Male		
Measures of Locomotion								
Total Distance (cm)	2393 (940.5)	2097 (338.6)	0.40 (-0.48, 1.29)	>0.99	2474 (1143)	2572 (1180)	-0.08 (-0.27, 0.80)	>0.99
Average Speed (cm/s)	7.84 (3.00)	6.95 (1.12)	0.38 (-0.51, 1.26)	>0.99	8.02 (3.81)	8.49 (3.92)	-0.12 (-1.63, 0.76)	>0.99
Average Walking Speed (cm/s)	2.10 (0.61)	2.09 (0.40)	0.02 (-0.86, 0.90)	>0.99	2.40 (1.46)	2.38 (1.08)	0.01 (-0.68, 0.89)	>0.99
Average Running Speed (cm/s)	24.1 (5.30)	22.1 (5.45)	0.36 (-0.53, 1.24)	>0.99	22.3 (5.73)	22.02 (9.70)	0.03 (-1.74, 0.91)	>0.99
Walking/ Running Distance	2.57 (0.93)	2.82 (0.89)	-0.26 (-1.14, 0.62)	>0.99	3.00 (1.09)	2.24 (0.64)	0.81 (-0.96, 1.73)	0.35
Walking/ Running Time	15.0 (11.23)	13.4 (4.85)	0.18 (-0.70, 1.06)	>0.99	13.3 (5.78)	9.24 (5.92)	0.66 (-0.99, 1.57)	0.89
Measures of Exploration								
Central/ Peripheral Distance	0.86 (0.77)	0.31 (0.20)	0.94 (-0.09, 1.86)	**0.035**	0.34 (0.16)	0.51 (0.26)	-0.75 (-1.66, 0.15)	>0.99
Central/ Peripheral Time	0.24 (0.20)	0.11 (0.08)	0.82 (-0.27, 1.73)	>0.99	0.16 (0.14)	0.34 (0.41)	-0.56 (-1.46, 0.33)	0.45
Central/ Peripheral Speed	3.66 (1.00)	2.93 (1.23)	0.62 (-1.52, 1.52)	0.48	2.42 (0.56)	2.13 (0.85)	0.39 (-0.50, 1.27)	>0.99
Total Freezing Counts	2615 (576.9)	3136 (782.5)	-0.73 (-0.18, 0.18)	>0.99	2759 (869.8)	2976 (843.1)	-0.24 (-1.12, 0.64)	>0.99
Central Freezing Counts	591 (458.1)	503 (381.4)	0.20 (0.01, 1.08)	>0.99	632 (651.4)	1031 (633.9)	-0.59 (-1.49, 0.30)	>0.99
Peripheral Freezing Counts	2024 (618.1)	2633 (782.6)	-0.83 (-0.09, 0.09)	0.38	2128 (382.6)	1945 (466.3)	0.41 (-0.47, 1.30)	>0.99

Table S8. Group means and effect sizes for locomotion and exploration measures comparing sexes within each treatment group. Mean values with standard deviations (SD) are reported for each locomotor and exploratory measure in control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Females served as the reference group for all comparisons. Adjusted *P*-values were calculated using Bonferroni's multiple comparisons post-hoc test.

Overall	Juvenile-Control		Juvenile-Acarbose		Juvenile -Rapamycin		Juvenile -Phenylbutyrate		Juvenile -Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion										
Total Distance (cm)	1.20 (0.58, 1.82)	**<0.0001**	1.52 (0.88, 2.16)	**<0.0001**	0.79 (0.20, 1.37)	**0.0051**	1.85 (1.18, 2.52)	**<0.0001**	1.44 (0.80, 2.07)	**<0.0001**
Average Speed (cm/s)	1.30 (0.67, 1.93)	**<0.0001**	1.53 (0.89, 2.17)	**<0.0001**	0.78 (0.20, 1.37)	**0.0060**	1.88 (1.21, 2.56)	**<0.0001**	1.47 (0.83, 2.10)	**<0.0001**
Average Walking Speed (cm/s)	1.32 (0.69, 1.95)	**<0.0001**	1.68 (1.03, 2.34)	**<0.0001**	1.16 (0.55, 1.77)	**<0.0001**	1.98 (1.30, 2.67)	**<0.0001**	1.56 (0.91, 2.20)	**<0.0001**
Average Running Speed (cm/s)	0.75 (0.16, 1.34)	**0.020**	1.46 (0.83, 2.09)	**<0.0001**	0.57 (-0.01, 1.14)	0.10	1.40 (0.77, 2.03)	**<0.0001**	1.37 (0.74, 2.00)	**<0.0001**
Walking/Running Distance	-0.55 (-1.14, 0.03)	0.75	-1.23 (-1.85, -0.62)	**0.0002**	-0.68 (-1.26, -0.10)	0.45	-1.22 (-1.83, -0.60)	**0.0077**	-1.05 (-1.66, -0.45)	**0.020**
Walking/Running Time	-1.14 (-1.75, -0.52)	0.10	-1.26 (-1.88, -0.64)	**0.0004**	-0.87 (-1.46, -0.28)	0.24	-1.28 (-1.89, -0.66)	**0.0002**	-1.02 (-1.63, -0.42)	**0.048**
Measures of Exploration										
Central/Peripheral Distance	0.55 (-0.04, 1.13)	0.12	0.90 (0.30, 1.49)	**0.0011**	0.11 (-0.46, 0.67)	0.99	0.39 (-0.18, 0.96)	0.28	0.69 (0.11, 1.28)	**0.027**
Central/Peripheral Time	0.65 (0.06, 1.24)	**<0.0001**	0.32 (-0.25, 0.89)	**<0.0001**	0.00 (-0.57, 0.57)	**0.0018**	0.68 (0.10, 1.26)	**<0.0001**	0.38 (-0.19, 0.95)	**<0.0001**
Central/Peripheral Speed	-0.77 (-1.37, -0.18)	**0.029**	-0.44 (-1.02, 0.13)	0.28	0.06 (-0.51, 0.62)	>0.99	-0.88 (-1.47, -0.29)	**0.0043**	0.06 (-0.50, 0.63)	>0.99
Total Freezing Counts	0.61 (0.03, 1.20)	0.19	-0.13 (-0.69, 0.44)	0.98	-0.87 (-1.46, -0.28)	**0.0098**	-0.03 (-0.60, 0.53)	>0.99	-0.02 (-0.59, 0.54)	>0.99
Central Freezing Counts	0.87 (0.27, 1.47)	**0.0076**	0.80 (0.21, 1.39)	**0.0055**	-0.32 (-0.89, 0.25)	0.46	0.71 (0.13, 1.29)	**0.036**	0.37 (-0.20, 0.94)	0.47
Peripheral Freezing Counts	-0.34 (-0.92, 0.24)	0.79	-1.13 (-1.74, -0.53)	**0.0001**	-0.73 (-1.31, -0.15)	0.09	-0.98 (-1.58, -0.39)	**0.010**	-0.68 (-1.26, -0.10)	0.31
Female	Juvenile-Control		Juvenile-Acarbose		Juvenile -Rapamycin		Juvenile -Phenylbutyrate		Juvenile -Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion										
Total Distance (cm)	1.23 (0.33, 2.12)	**0.0042**	1.47 (0.57, 2.37)	**0.0002**	1.01 (0.16, 1.85)	**0.020**	1.46 (0.57, 2.36)	**0.0002**	1.34 (0.45, 2.22)	**0.0005**

Average Speed (cm/s)	1.34 (0.43, 2.25)	**0.002**	1.49 (0.59, 2.39)	**0.0002**	1.01 (0.16, 1.86)	**0.021**	1.52 (0.62, 2.42)	**0.0002**	1.39 (0.50, 2.27)	**0.0003**
Average Walking Speed (cm/s)	1.42 (0.50, 2.33)	**0.0001**	1.59 (0.68, 2.51)	**<0.0001**	1.40 (0.51, 2.29)	**0.0002**	1.71 (0.78, 2.64)	**<0.0001**	1.32 (0.44, 2.20)	**<0.0001**
Average Running Speed (cm/s)	0.80 (-0.06, 1.65)	**0.03**	1.53 (0.62, 2.43)	**<0.0001**	0.85 (0.02, 1.69)	**0.021**	1.21 (0.34, 2.07)	**0.0007**	1.39 (0.50, 2.27)	**<0.0001**
Walking/Running Distance	-0.48 (-1.31, 0.36)	0.90	-1.20 (-2.06, -0.33)	**0.011**	-0.53 (-1.35, 0.28)	0.87	-0.95 (-1.79, -0.11)	0.24	-1.40 (-2.28, -0.51)	**0.0093**
Walking/Running Time	-1.07 (-1.95, -0.19)	0.33	-1.08 (-1.93, -0.22)	**0.026**	-0.66 (-1.48, 0.16)	0.84	-1.01 (-1.85, -0.16)	**0.011**	-1.38 (-2.27, -0.49)	0.07
Measures of Exploration										
Central/Peripheral Distance	0.52 (-0.32, 1.36)	0.29	0.96 (0.12, 1.81)	**0.006**	0.32 (-0.48, 1.13)	0.68	0.03 (-0.77, 0.83)	>0.99	0.70 (-0.12, 1.53)	0.07
Central/Peripheral Time	0.56 (-0.28, 1.40)	0.40	0.90 (0.07, 1.74)	0.06	0.20 (-0.60, 1.01)	0.96	0.30 (-0.50, 1.10)	0.83	0.56 (-0.25, 1.38)	0.35
Central/Peripheral Speed	-0.81 (-1.66, 0.05)	0.09	-0.28 (-1.09, 0.52)	0.80	0.05 (-0.75, 0.85)	>0.99	-1.02 (-1.87, -0.17)	**0.015**	0.03 (-0.77, 0.83)	>0.99
Total Freezing Counts	1.06 (0.18, 1.93)	0.27	0.03 (-0.77, 0.83)	>0.99	-1.25 (-2.12, -0.37)	0.07	0.17 (-0.64, 0.97)	>0.99	-0.03 (-0.83, 0.77)	>0.99
Central Freezing Counts	0.90 (0.03, 1.76)	0.16	1.18 (0.31, 2.04)	**0.032**	-0.25 (-1.05, 0.56)	0.94	0.57 (-0.24, 1.39)	0.51	0.49 (-0.32, 1.30)	0.60
Peripheral Freezing Counts	-0.01 (-0.83, 0.82)	>0.99	-1.07 (-1.92, -0.22)	**0.018**	-1.16 (-2.02, -0.29)	0.08	-0.65 (-1.47, 0.17)	0.68	-1.03 (-1.88, -0.18)	0.43
Male	Juvenile-Control		Juvenile-Acarbose		Juvenile -Rapamycin		Juvenile -Phenylbutyrate		Juvenile -Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion										
Total Distance (cm)	1.11 (0.25, 1.97)	**0.016**	1.46 (0.56, 2.36)	**0.0006**	0.56 (-0.26, 1.37)	0.29	2.19 (1.19, 3.20)	**<0.0001**	1.46 (0.57, 2.36)	**0.0002**
Average Speed (cm/s)	1.19 (0.32, 2.05)	**0.009**	1.45 (0.56, 2.35)	**0.0006**	0.55 (-0.27, 1.36)	0.31	2.17 (1.17, 3.17)	**<0.0001**	1.44 (0.54, 2.33)	**0.0003**
Average Walking Speed (cm/s)	1.18 (0.32, 2.05)	**0.0029**	1.68 (0.75, 2.60)	**<0.0001**	0.91 (0.07, 1.75)	**0.014**	2.15 (1.15, 3.15)	**<0.0001**	1.74 (0.80, 2.67)	**<0.0001**
Average Running Speed (cm/s)	0.70 (-0.12, 1.52)	0.55	1.37 (0.48, 2.25)	**0.026**	0.14 (-0.66, 0.94)	>0.99	1.70 (0.77, 2.63)	**0.0023**	1.29 (0.42, 2.17)	**0.0021**

Walking/Running Distance	-0.61 (-1.43, 0.20)	0.95	-1.16 (-2.02, -0.30)	**0.016**	-0.75 (-1.57, 0.08)	0.64	-1.45 (-2.34, -0.55)	**0.040**	-0.66 (-1.48, 0.16)	0.84
Walking/Running Time	-1.25 (-2.12, -0.38)	0.45	-1.43 (-2.32, -0.54)	**0.022**	-0.99 (-1.84, -0.15)	0.34	-1.97 (-2.94, -1.00)	**0.021**	-0.69 (-1.52, 0.13)	0.67
Measures of Exploration										
Central/Peripheral Distance	0.57 (-0.25, 1.38)	0.53	0.77 (-0.06, 1.60)	0.15	-0.16 (-0.96, 0.65)	0.99	1.03 (0.18, 1.88)	0.07	0.64 (-0.18, 1.46)	0.41
Central/Peripheral Time	0.71 (-0.12, 1.53)	0.30	0.94 (0.10, 1.78)	0.06	-0.18 (-0.98, 0.62)	0.96	1.14 (0.28, 2.00)	**0.035**	0.21 (-0.59, 1.02)	0.96
Central/Peripheral Speed	-0.74 (-1.56, 0.09)	0.36	-0.67 (-1.49, 0.16)	0.44	0.06 (-0.75, 0.86)	>0.99	-0.70 (-1.52, 0.13)	0.28	0.09 (-0.71, 0.89)	>0.99
Total Freezing Counts	0.38 (-0.43, 1.19)	0.76	-0.25 (-1.06, 0.55)	0.90	-0.62 (-1.44, 0.19)	0.20	-0.17 (-0.97, 0.63)	0.99	-0.02 (-0.82, 0.78)	>0.99
Central Freezing Counts	0.82 (-0.01, 1.66)	0.06	0.55 (-0.26, 1.37)	0.21	-0.36 (-1.17, 0.44)	0.53	0.79 (-0.04, 1.62)	0.08	0.25 (-0.55, 1.05)	0.91
Peripheral Freezing Counts	-0.51 (-1.32, 0.30)	0.53	-1.11 (-1.97, -0.25)	**0.0078**	-0.38 (-1.18, 0.43)	0.81	-1.26 (-2.13, -0.39)	**0.0070**	-0.43 (-1.24, 0.38)	0.84

Table S9. Effect sizes for locomotion and exploration measures across treatment groups compared to juveniles. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for each locomotor and exploratory measure in juvenile, control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Juveniles served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

Overall	Adult-Control		Adult-Acarbose		Adult-Rapamycin		Adult-Phenylbutyrate		Adult-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion										
Total Distance (cm)	-0.82 (-1.42, -0.23)	**0.041**	-0.39 (-0.96, 0.18)	0.59	-1.06 (-1.66, -0.46)	**0.0004**	-0.09 (-0.66, 0.48)	>0.99	-0.36 (-0.93, 0.21)	0.64
Average Speed (cm/s)	-0.71 (-1.31, -0.12)	0.10	-0.39 (-0.96, 0.18)	0.60	-1.06 (-1.67, -0.46)	**0.0003**	-0.08 (-0.64, 0.49)	>0.99	-0.32 (-0.88, 0.25)	0.70
Average Walking Speed (cm/s)	-0.89 (-1.49, -0.29)	**0.017**	-0.49 (-1.06, 0.09)	0.47	-0.96 (-1.56, -0.37)	**0.0021**	-0.15 (-0.71, 0.42)	>0.99	-0.39 (-0.96, 0.18)	0.50
Average Running Speed (cm/s)	-0.77 (-1.37, -0.18)	**0.0044**	-0.28 (-0.84, 0.29)	0.66	-0.89 (-1.48, -0.30)	**0.0005**	-0.31 (-0.88, 0.25)	0.54	-0.21 (-0.78, 0.36)	0.82
Walking/Running Distance	0.52 (-0.06, 1.11)	0.26	-0.20 (-0.76, 0.37)	0.89	0.42 (-0.15, 0.99)	0.44	0.03 (-0.54, 0.59)	>0.99	0.09 (-0.48, 0.66)	>0.99

Walking/Running Time	-0.09 (-0.67, 0.48)	>0.99	-0.50 (-1.07, 0.08)	0.24	0.03 (-0.53, 0.60)	>0.99	-0.54 (-1.12, 0.04)	0.16	-0.16 (-0.73, 0.40)	0.98
Measures of Exploration										
Central/Peripheral Distance	0.48 (-0.10, 1.07)	0.09	0.71 (0.12, 1.29)	**0.0030**	0.22 (-0.35, 0.78)	0.72	0.40 (-0.17, 0.97)	0.17	0.57 (0.00, 1.15)	**0.028**
Central/Peripheral Time	0.15 (-0.42, 0.73)	**0.0004**	-0.13 (-0.70, 0.44)	**0.0010**	-0.55 (-1.13, 0.02)	**0.0071**	0.20 (-0.37, 0.77)	**0.0002**	-0.11 (-0.68, 0.45)	**0.0008**
Central/Peripheral Speed	0.33 (-0.25, 0.91)	0.43	0.48 (-0.10, 1.05)	0.09	0.84 (0.25, 1.43)	**0.0014**	0.24 (-0.33, 0.80)	0.71	0.83 (0.24, 1.42)	**0.0012**
Total Freezing Counts	0.20 (-0.38, 0.77)	0.93	-0.37 (-0.94, 0.20)	0.39	-1.01 (-1.61, -0.41)	**0.0005**	-0.33 (-0.90, 0.24)	0.65	-0.32 (-0.88, 0.25)	0.67
Central Freezing Counts	0.62 (0.03, 1.20)	0.08	0.57 (0.00, 1.15)	0.07	-0.46 (-1.03, 0.11)	0.12	0.47 (-0.10, 1.04)	0.25	0.16 (-0.40, 0.73)	0.95
Peripheral Freezing Counts	-0.56 (-1.14, 0.03)	0.32	-1.31 (-1.93, -0.69)	**<0.0001**	-0.94 (-1.54, -0.35)	**0.013**	-1.20 (-1.81, -0.59)	**0.0010**	-0.95 (-1.54, -0.35)	0.07
<u>Female</u>	Adult -Control		Adult -Acarbose		Adult -Rapamycin		Adult -Phenylbutyrate		Adult -Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion										
Total Distance (cm)	-0.65 (-1.50, 0.19)	0.42	-0.34 (-1.15, 0.46)	0.89	-0.92 (-1.75, -0.08)	0.10	-0.33 (-1.14, 0.47)	0.89	-0.38 (-1.19, 0.43)	0.79
Average Speed (cm/s)	-0.58 (-1.43, 0.26)	0.56	-0.36 (-1.16, 0.45)	0.88	-0.94 (-1.79, -0.10)	0.08	-0.33 (-1.14, 0.48)	0.91	-0.35 (-1.15, 0.46)	0.84
Average Walking Speed (cm/s)	-0.72 (-1.57, 0.13)	0.37	-0.53 (-1.35, 0.28)	0.68	-0.95 (-1.79, -0.11)	0.17	-0.41 (-1.22, 0.40)	0.88	-0.54 (-1.35, 0.28)	0.38
Average Running Speed (cm/s)	-0.64 (-1.49, 0.20)	0.09	-0.16 (-0.96, 0.64)	0.98	-0.65 (-1.47, 0.17)	0.09	-0.41 (-1.22, 0.40)	0.49	-0.25 (-1.06, 0.55)	0.86
Walking/Running Distance	0.31 (-0.52, 1.14)	0.97	-0.47 (-1.28, 0.34)	0.63	0.31 (-0.50, 1.11)	0.97	-0.10 (-0.90, 0.70)	>0.99	-0.54 (-1.35, 0.28)	0.60
Walking/Running Time	-0.46 (-1.29, 0.38)	0.87	-0.69 (-1.52, 0.13)	0.24	-0.09 (-0.89, 0.71)	>0.99	-0.69 (-1.51, 0.13)	0.14	-0.74 (-1.56, 0.09)	0.45
Measures of Exploration										
Central/Peripheral Distance	0.53 (-0.31, 1.37)	0.45	0.91 (0.07, 1.75)	**0.045**	0.36 (-0.44, 1.17)	0.74	0.11 (-0.69, 0.91)	>0.99	0.69 (-0.14, 1.51)	0.19

Central/Peripheral Time	0.24 (-0.59, 1.07)	>0.99	0.92 (0.08, 1.76)	0.51	-0.33 (-1.13, 0.48)	0.92	-0.21 (-1.01, 0.60)	>0.99	0.23 (-0.57, 1.04)	0.99
Central/Peripheral Speed	0.24 (-0.59, 1.07)	0.90	0.50 (-0.31, 1.32)	0.25	0.81 (-0.02, 1.64)	**0.039**	0.12 (-0.68, 0.92)	0.99	0.80 (-0.03, 1.63)	**0.042**
Total Freezing Counts	0.51 (-0.33, 1.35)	0.63	-0.11 (-0.91, 0.69)	>0.99	-1.02 (-1.87, -0.17)	**0.037**	-0.05 (-0.86, 0.75)	>0.99	-0.18 (-0.98, 0.62)	0.98
Central Freezing Counts	0.76 (-0.10, 1.61)	0.22	1.00 (0.15, 1.85)	0.054	-0.26 (-1.06, 0.55)	0.91	0.48 (-0.33, 1.29)	0.62	0.41 (-0.40, 1.22)	0.71
Peripheral Freezing Counts	-0.26 (-1.09, 0.57)	0.99	-1.17 (-2.03, -0.30)	**0.0041**	-1.25 (-2.12, -0.37)	**0.025**	-0.80 (-1.63, 0.03)	0.35	-1.12 (-1.97, -0.26)	0.18
Male	Adult-Control		Adult -Acarbose		Adult -Rapamycin		Adult -Phenylbutyrate		Adult -Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion										
Total Distance (cm)	-0.94 (-1.78, -0.10)	0.15	-0.43 (-1.24, 0.38)	0.81	-1.16 (-2.02, -0.30)	**0.004**	0.24 (-0.56, 1.05)	0.99	-0.28 (-1.08, 0.52)	0.94
Average Speed (cm/s)	-0.80 (-1.63, 0.03)	0.27	-0.40 (-1.21, 0.40)	0.84	-1.14 (-2.00, -0.28)	**0.004**	0.25 (-0.55, 1.05)	0.99	-0.27 (-1.07, 0.54)	0.95
Average Walking Speed (cm/s)	-1.06 (-1.92, -0.21)	0.06	-0.44 (-1.25, 0.37)	0.84	-1.03 (-1.88, -0.18)	**0.010**	0.16 (-0.64, 0.96)	>0.99	-0.19 (-0.99, 0.61)	0.99
Average Running Speed (cm/s)	-0.90 (-1.74, -0.06)	0.08	-0.42 (-1.23, 0.39)	0.72	-1.17 (-2.03, -0.31)	**0.007**	-0.17 (-0.97, 0.63)	0.99	-0.14 (-0.94, 0.66)	0.99
Walking/Running Distance	0.68 (-0.14, 1.50)	0.19	0.02 (-0.78, 0.82)	>0.99	0.50 (-0.31, 1.31)	0.43	0.11 (-0.69, 0.91)	0.99	0.59 (-0.22, 1.41)	0.28
Walking/Running Time	0.22 (-0.59, 1.02)	0.99	-0.27 (-1.08, 0.53)	0.93	0.14 (-0.66, 0.94)	>0.99	-0.32 (-1.12, 0.49)	0.92	0.31 (-0.50, 1.11)	0.92
Measures of Exploration										
Central/Peripheral Distance	0.44 (-0.37, 1.25)	0.27	0.56 (-0.26, 1.37)	0.09	0.11 (-0.69, 0.91)	>0.99	0.63 (-0.19, 1.45)	0.053	0.47 (-0.34, 1.28)	0.21
Central/Peripheral Time	0.04 (-0.76, 0.84)	>0.99	0.37 (-0.44, 1.18)	0.82	-0.76 (-1.58, 0.07)	**0.039**	0.58 (-0.24, 1.39)	0.65	-0.33 (-1.14, 0.48)	0.70
Central/Peripheral Speed	0.39 (-0.42, 1.20)	0.61	0.42 (-0.39, 1.23)	0.54	0.81 (-0.02, 1.64)	0.053	0.35 (-0.46, 1.15)	0.68	0.80 (-0.03, 1.63)	**0.044**
Total Freezing Counts	-0.06 (-0.86, 0.74)	>0.99	-0.60 (-1.42, 0.22)	0.22	-0.94 (-1.79, -0.10)	**0.016**	-0.57 (-1.39, 0.24)	0.40	-0.43 (-1.23, 0.38)	0.67

Central Freezing Counts	0.47 (-0.35, 1.28)	0.51	0.26 (-0.55, 1.06)	0.85	-0.60 (-1.41, 0.22)	0.10	0.43 (-0.37, 1.24)	0.57	-0.06 (-0.86, 0.74)	>0.99
Peripheral Freezing Counts	-0.75 (-1.58, 0.08)	0.23	-1.37 (-2.25, -0.48)	**0.0014**	-0.62 (-1.44, 0.20)	0.46	-1.57 (-2.48, -0.66)	**0.0013**	-0.74 (-1.56, 0.09)	0.49

Table S10. Effect sizes for locomotion and exploration measures across treatment groups compared to adults. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for each locomotor and exploratory measure in adult, control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Adults served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

Overall	Geriatric-Control		Geriatric-Acarbose		Geriatric-Rapamycin		Geriatric-Phenylbutyrate		Geriatric-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion										
Total Distance (cm)	-0.94 (-1.50, -0.38)	**0.0067**	-0.51 (-1.05, 0.02)	0.27	-1.20 (-1.77, -0.63)	**<0.0001**	-0.21 (-0.74, 0.32)	0.95	-0.48 (-1.01, 0.06)	0.31
Average Speed (cm/s)	-0.88 (-1.43, -0.32)	**0.014**	-0.55 (-1.09, -0.01)	0.21	-1.24 (-1.81, -0.68)	**<0.0001**	-0.25 (-0.78, 0.28)	0.90	-0.47 (-1.01, 0.06)	0.27
Average Walking Speed (cm/s)	-0.78 (-1.34, -0.23)	**0.022**	-0.38 (-0.91, 0.15)	0.61	-0.89 (-1.43, -0.34)	**0.0024**	-0.05 (-0.57, 0.48)	>0.99	-0.32 (-0.85, 0.21)	0.65
Average Running Speed (cm/s)	-1.21 (-1.79, -0.63)	**<0.0001**	-0.52 (-1.05, 0.02)	0.17	-1.35 (-1.93, -0.78)	**<0.0001**	-0.57 (-1.11, -0.03)	0.11	-0.41 (-0.94, 0.12)	0.32
Walking/Running Distance	0.91 (0.35, 1.47)	**0.0008**	0.30 (-0.23, 0.83)	0.51	0.83 (0.28, 1.37)	**0.0019**	0.52 (-0.02, 1.05)	0.10	0.56 (0.03, 1.10)	0.055
Walking/Running Time	0.57 (0.02, 1.11)	0.12	0.18 (-0.35, 0.70)	0.93	0.65 (0.11, 1.19)	**0.043**	0.13 (-0.40, 0.66)	0.98	0.49 (-0.05, 1.02)	0.18
Measures of Exploration										
Central/Peripheral Distance	-1.16 (-1.74, -0.59)	0.076	-0.07 (-0.60, 0.46)	>0.99	-1.37 (-1.95, -0.79)	**<0.0001**	-0.87 (-1.42, -0.32)	**0.0098**	-0.80 (-1.34, -0.25)	0.39
Central/Peripheral Time	-0.47 (-1.01, 0.07)	0.95	-0.55 (-1.08, -0.01)	>0.99	-1.10 (-1.66, -0.54)	0.27	-0.39 (-0.92, 0.14)	0.86	-0.61 (-1.14, -0.07)	>0.99
Central/Peripheral Speed	-0.44 (-0.98, 0.10)	0.29	-0.18 (-0.71, 0.34)	0.92	0.31 (-0.22, 0.83)	0.74	-0.56 (-1.10, -0.03)	0.08	0.30 (-0.22, 0.83)	0.71
Total Freezing Counts	-0.26 (-0.79, 0.28)	0.81	-0.78 (-1.32, -0.23)	**0.0031**	-1.43 (-2.01, -0.84)	**<0.0001**	-0.77 (-1.32, -0.23)	**0.011**	-0.75 (-1.29, -0.21)	**0.012**

Central Freezing Counts	-0.03 (-0.56, 0.51)	>0.99	-0.01 (-0.54, 0.51)	>0.99	-1.01 (-1.57, -0.46)	**<0.0001**	-0.17 (-0.69, 0.36)	0.95	-0.44 (-0.97, 0.09)	0.23
Peripheral Freezing Counts	-0.33 (-0.87, 0.21)	0.67	-1.08 (-1.63, -0.52)	**<0.0001**	-0.67 (-1.21, -0.13)	0.051	-0.88 (-1.43, -0.33)	**0.0050**	-0.57 (-1.10, -0.03)	0.21
Female	Geriatric-Control		Geriatric-Acarbose		Geriatric Rapamycin		Geriatric-Phenylbutyrate		Geriatric-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion										
Total Distance (cm)	-0.73 (-1.53, 0.07)	0.33	-0.40 (-1.16, 0.36)	0.83	-1.01 (-1.80, -0.21)	0.06	-0.39 (-1.14, 0.37)	0.84	-0.44 (-1.20, 0.32)	0.70
Average Speed (cm/s)	-0.73 (-1.53, 0.07)	0.35	-0.49 (-1.25, 0.28)	0.69	-1.11 (-1.92, -0.31)	**0.03**	-0.46 (-1.22, 0.30)	0.74	-0.47 (-1.24, 0.29)	0.64
Average Walking Speed (cm/s)	-0.26 (-1.04, 0.52)	0.95	-0.08 (-0.84, 0.67)	>0.99	-0.40 (-1.16, 0.36)	0.76	0.04 (-0.71, 0.79)	>0.99	-0.20 (-0.96, 0.55)	0.96
Average Running Speed (cm/s)	-1.10 (-1.92, -0.27)	**0.006**	-0.39 (-1.14, 0.37)	0.76	-1.12 (-1.92, -0.31)	**0.0054**	-0.77 (-1.55, 0.01)	0.12	-0.52 (-1.29, 0.24)	0.46
Walking/Running Distance	0.71 (-0.09, 1.51)	0.19	0.11 (-0.64, 0.87)	0.99	0.72 (-0.05, 1.49)	0.17	0.44 (-0.32, 1.20)	0.62	0.10 (-0.65, 0.86)	>0.99
Walking/Running Time	0.30 (-0.49, 1.08)	0.89	0.00 (-0.75, 0.76)	>0.99	0.54 (-0.23, 1.30)	0.41	-0.07 (-0.82, 0.69)	>0.99	0.12 (-0.64, 0.87)	>0.99
Measures of Exploration										
Central/Peripheral Distance	-0.87 (-1.68, -0.06)	0.50	0.47 (-0.29, 1.23)	0.94	-1.04 (-1.83, -0.24)	0.06	-1.24 (-2.05, -0.42)	**0.0004**	-0.38 (-1.13, 0.38)	0.98
Central/Peripheral Time	-0.16 (-0.94, 0.62)	>0.99	0.40 (-0.36, 1.16)	0.92	-0.64 (-1.41, 0.13)	0.31	-0.54 (-1.30, 0.23)	0.59	-0.16 (-0.91, 0.59)	>0.99
Central/Peripheral Speed	-0.58 (-1.37, 0.22)	0.35	-0.09 (-0.84, 0.67)	>0.99	0.30 (-0.45, 1.06)	0.90	-0.79 (-1.57, -0.01)	0.08	0.29 (-0.47, 1.04)	0.92
Total Freezing Counts	0.26 (-0.53, 1.04)	0.88	-0.20 (-0.96, 0.55)	0.92	-0.89 (-1.68, -0.11)	**0.0067**	-0.16 (-0.92, 0.59)	0.98	-0.25 (-1.01, 0.50)	0.85
Central Freezing Counts	0.20 (-0.59, 0.98)	0.91	0.34 (-0.42, 1.10)	0.52	-0.46 (-1.22, 0.30)	0.17	0.02 (-0.73, 0.78)	>0.99	-0.01 (-0.76, 0.75)	>0.99
Peripheral Freezing Counts	0.10 (-0.68, 0.88)	>0.99	-0.73 (-1.50, 0.05)	**0.044**	-0.64 (-1.41, 0.13)	0.18	-0.28 (-1.04, 0.48)	0.89	-0.41 (-1.17, 0.35)	0.67
Male	Geriatric-Control		Geriatric -Acarbose		Geriatric -Rapamycin		Geriatric -Phenylbutyrate		Geriatric -Combined	

	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion										
Total Distance (cm)	-1.09 (-1.87, -0.31)	**0.03**	-0.60 (-1.36, 0.15)	0.41	-1.36 (-2.17, -0.56)	**0.0002**	-0.01 (-0.75, 0.73)	>0.99	-0.46 (-1.21, 0.29)	0.62
Average Speed (cm/s)	-0.97 (-1.74, -0.19)	0.06	-0.60 (-1.35, 0.15)	0.42	-1.35 (-2.16, -0.55)	**0.0002**	-0.02 (-0.76, 0.71)	>0.99	-0.46 (-1.20, 0.29)	0.61
Average Walking Speed (cm/s)	-1.14 (-1.93, -0.36)	**0.02**	-0.53 (-1.28, 0.21)	0.62	-1.17 (-1.95, -0.38)	**0.0024**	-0.01 (-0.75, 0.73)	>0.99	-0.30 (-1.05, 0.44)	0.93
Average Running Speed (cm/s)	-1.24 (-2.04, -0.45)	**0.004**	-0.65 (-1.40, 0.10)	0.28	-1.56 (-2.38, -0.73)	**<0.0001**	-0.35 (-1.09, 0.40)	0.83	-0.29 (-1.03, 0.45)	0.85
Walking/Running Distance	1.05 (0.27, 1.83)	**0.0044**	0.45 (-0.29, 1.20)	0.40	0.89 (0.13, 1.66)	**0.017**	0.55 (-0.20, 1.30)	0.26	0.98 (0.20, 1.75)	**0.0080**
Walking/Running Time	0.82 (0.06, 1.58)	0.13	0.35 (-0.39, 1.10)	0.80	0.73 (-0.03, 1.49)	0.17	0.37 (-0.38, 1.11)	0.81	0.87 (0.11, 1.64)	0.07
Measures of Exploration										
Central/Peripheral Distance	-1.42 (-2.23, -0.61)	0.16	-0.42 (-1.17, 0.32)	0.84	-1.69 (-2.53, -0.85)	**<0.0001**	-0.37 (-1.11, 0.38)	0.99	-1.28 (-2.08, -0.48)	0.28
Central/Peripheral Time	-0.89 (-1.65, -0.12)	0.62	-0.14 (-0.88, 0.59)	>0.99	-1.50 (-2.32, -0.68)	**<0.0001**	0.11 (-0.63, 0.85)	>0.99	-0.93 (-1.70, -0.16)	**0.027**
Central/Peripheral Speed	-0.50 (-1.25, 0.24)	0.59	-0.45 (-1.19, 0.30)	0.68	0.21 (-0.53, 0.95)	0.99	-0.52 (-1.26, 0.23)	0.48	0.23 (-0.51, 0.97)	0.98
Total Freezing Counts	-1.19 (-1.98, -0.40)	0.11	-1.79 (-2.65, -0.94)	**0.0003**	-2.34 (-3.26, -1.41)	**<0.0001**	-2.09 (-2.98, -1.20)	**0.0012**	-1.80 (-2.66, -0.95)	**0.005**
Central Freezing Counts	-1.34 (-2.14, -0.53)	0.87	-0.84 (-1.60, -0.07)	0.51	-2.24 (-3.15, -1.33)	**<0.0001**	-1.37 (-2.17, -0.56)	0.82	-2.35 (-3.27, -1.42)	**0.042**
Peripheral Freezing Counts	-0.84 (-1.60, -0.07)	0.21	-1.53 (-2.35, -0.71)	**0.0010**	-0.69 (-1.45, 0.06)	0.44	-1.73 (-2.57, -0.88)	**0.0009**	-0.79 (-1.55, -0.03)	0.48

Table S11. Effect sizes for locomotion and exploration measures across treatment groups compared to historical geriatrics. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for each locomotor and exploratory measure in historical geriatrics, control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Historical geriatrics served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

Overall	Pooled Control-Acarbose		Pooled Control-Rapamycin		Pooled Control-Phenylbutyrate		Pooled Control-SLAM	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion								
Total Distance (cm)	-0.23 (-0.73, 0.28)	0.85	-0.94 (-1.46, -0.42)	**0.0006**	0.08 (-0.43, 0.58)	>0.99	-0.20 (-0.70, 0.31)	0.89
Average Speed (cm/s)	-0.29 (-0.79, 0.21)	0.70	-1.02 (-1.54, -0.49)	**0.0002**	0.02 (-0.48, 0.52)	>0.99	-0.24 (-0.74, 0.27)	0.80
Average Walking Speed (cm/s)	-0.12 (-0.62, 0.38)	0.98	-0.65 (-1.16, -0.14)	**0.025**	0.20 (-0.30, 0.70)	0.92	-0.10 (-0.60, 0.40)	0.99
Average Running Speed (cm/s)	-0.15 (-0.65, 0.35)	0.95	-0.95 (-1.47, -0.43)	**0.0003**	-0.19 (-0.70, 0.31)	0.87	-0.07 (-0.57, 0.43)	>0.99
Walking/Running Distance	0.06 (-0.44, 0.57)	>0.99	0.57 (0.06, 1.08)	0.057	0.26 (-0.24, 0.77)	0.68	0.31 (-0.19, 0.82)	0.51
Walking/Running Time	0.03 (-0.48, 0.53)	>0.99	0.52 (0.01, 1.03)	0.16	-0.02 (-0.52, 0.48)	>0.99	0.35 (-0.15, 0.86)	0.48
Measures of Exploration								
Central/Peripheral Distance	0.22 (-0.29, 0.72)	0.95	-1.22 (-1.76, -0.68)	**<0.0001**	-0.69 (-1.20, -0.18)	0.054	-0.38 (-0.89, 0.12)	0.82
Central/Peripheral Time	-0.12 (-0.62, 0.38)	0.98	-0.61 (-1.13, -0.10)	0.12	0.28 (-0.23, 0.78)	0.90	-0.10 (-0.60, 0.41)	>0.99
Central/Peripheral Speed	-0.07 (-0.57, 0.44)	>0.99	0.45 (-0.06, 0.95)	0.28	-0.46 (-0.96, 0.05)	0.19	0.44 (-0.06, 0.95)	0.25
Total Freezing Counts	-0.77 (-1.28, -0.25)	**0.0042**	-1.45 (-2.00, -0.91)	**<0.0001**	-0.74 (-1.26, -0.23)	**0.016**	-0.72 (-1.23, -0.21)	**0.017**
Central Freezing Counts	-0.01 (-0.51, 0.49)	>0.99	-1.14 (-1.67, -0.61)	**<0.0001**	-0.18 (-0.68, 0.32)	0.92	-0.49 (-1.00, 0.02)	0.17
Peripheral Freezing Counts	-1.03 (-1.55, -0.50)	**<0.0001**	-0.46 (-0.97, 0.05)	0.084	-0.80 (-1.31, -0.28)	**0.009**	-0.58 (-1.09, -0.07)	0.32
Female	Pooled Control-Acarbose		Pooled Control-Combined		Pooled Control-Phenylbutyrate		Pooled Control-Rapamycin	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value

Measures of Locomotion								
Total Distance (cm)	-0.26 (-0.97, 0.46)	0.93	-0.31 (-1.03, 0.40)	0.84	-0.25 (-0.96, 0.46)	0.94	-0.85 (-1.58, -0.12)	0.10
Average Speed (cm/s)	-0.23 (-0.95, 0.49)	0.95	-0.24 (-0.97, 0.48)	0.93	-0.20 (-0.93, 0.52)	0.97	-0.84 (-1.59, -0.09)	0.11
Average Walking Speed (cm/s)	-0.03 (-0.74, 0.68)	>0.99	-0.17 (-0.88, 0.54)	0.97	0.10 (-0.61, 0.81)	>0.99	-0.37 (-1.08, 0.35)	0.78
Average Running Speed (cm/s)	0.01 (-0.70, 0.72)	>0.99	-0.13 (-0.84, 0.58)	0.99	-0.35 (-1.06, 0.36)	0.71	-0.69 (-1.42, 0.03)	0.11
Walking/Running Distance	-0.12 (-0.83, 0.59)	0.99	-0.14 (-0.85, 0.57)	0.99	0.20 (-0.51, 0.91)	0.96	0.49 (-0.23, 1.21)	0.52
Walking/Running Time	-0.07 (-0.78, 0.64)	>0.99	0.04 (-0.67, 0.75)	>0.99	-0.15 (-0.86, 0.56)	0.97	0.51 (-0.21, 1.23)	0.47
Measures of Exploration								
Central/Peripheral Distance	0.75 (0.01, 1.49)	0.58	-0.08 (-0.80, 0.64)	>0.99	-1.19 (-1.95, -0.42)	**0.001**	-0.88 (-1.63, -0.13)	0.15
Central/Peripheral Time	0.49 (-0.24, 1.22)	0.77	-0.11 (-0.84, 0.61)	>0.99	-0.53 (-1.26, 0.20)	0.60	-0.65 (-1.38, 0.09)	0.31
Central/Peripheral Speed	0.03 (-0.69, 0.75)	>0.99	0.44 (-0.29, 1.17)	0.58	-0.67 (-1.41, 0.07)	0.15	0.46 (-0.27, 1.19)	0.55
Total Freezing Counts	-0.31 (-1.03, 0.41)	0.69	-0.37 (-1.09, 0.35)	0.58	-0.27 (-0.99, 0.45)	0.83	-1.09 (-1.85, -0.34)	**0.0013**
Central Freezing Counts	0.32 (-0.40, 1.04)	0.60	-0.07 (-0.79, 0.64)	>0.99	-0.04 (-0.76, 0.67)	>0.99	-0.59 (-1.32, 0.14)	0.061
Peripheral Freezing Counts	-0.85 (-1.59, -0.11)	**0.020**	-0.49 (-1.21, 0.23)	0.51	-0.34 (-1.06, 0.38)	0.76	-0.74 (-1.47, -0.01)	0.10
Male	Pooled Control-Acarbose		Pooled Control-Combined		Pooled Control-Phenylbutyrate		Pooled Control-Rapamycin	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Measures of Locomotion								
Total Distance (cm)	-0.27 (-0.98, 0.43)	0.89	-0.16 (-0.86, 0.55)	0.98	0.31 (-0.40, 1.02)	0.87	-1.09 (-1.83, -0.35)	**0.0026**

Average Speed (cm/s)	-0.31 (-1.01, 0.40)	0.85	-0.20 (-0.90, 0.51)	0.96	0.27 (-0.44, 0.98)	0.92	-1.13 (-1.87, -0.39)	**0.0019**
Average Walking Speed (cm/s)	-0.15 (-0.86, 0.55)	0.98	0.03 (-0.68, 0.73)	>0.99	0.32 (-0.39, 1.03)	0.84	-0.84 (-0.11, -0.65)	**0.024**
Average Running Speed (cm/s)	-0.28 (-0.99, 0.43)	0.88	0.02 (-0.69, 0.72)	>0.99	0.01 (-0.70, 0.71)	>0.99	-1.18 (-1.93, -0.43)	**0.0026**
Walking/Running Distance	0.18 (-0.53, 0.89)	0.94	0.69 (-0.03, 1.41)	0.10	0.27 (-0.44, 0.97)	0.84	0.61 (-0.11, 1.33)	0.17
Walking/Running Time	0.14 (-0.56, 0.85)	0.99	0.68 (-0.04, 1.40)	0.21	0.14 (-0.56, 0.85)	0.99	0.53 (-0.19, 1.24)	0.44
Measures of Exploration								
Central/Peripheral Distance	-0.15 (-0.85, 0.56)	0.99	-0.70 (-1.42, 0.02)	0.59	0.08 (-0.62, 0.79)	>0.99	-1.54 (-2.32, -0.77)	**<0.0001**
Central/Peripheral Time	0.07 (-0.64, 0.77)	>0.99	-0.86 (-1.59, -0.13)	0.054	0.35 (-0.36, 1.06)	0.98	-1.48 (-2.25, -0.71)	**0.0001**
Central/Peripheral Speed	-0.30 (-1.01, 0.40)	0.85	0.38 (-0.33, 1.09)	0.74	-0.39 (-1.10, 0.32)	0.67	0.36 (-0.35, 1.07)	0.81
Total Freezing Counts	-1.40 (-2.17, -0.64)	**0.002**	-1.24 (-1.99, -0.49)	**0.024**	-1.46 (-2.23, -0.69)	**0.007**	-1.89 (-2.70, -1.08)	**<0.0001**
Central Freezing Counts	-0.73 (-1.45, -0.01)	0.60	-2.04 (-2.87, -1.22)	0.052	-0.82 (-1.55, -0.10)	0.89	-2.32 (-3.17, -1.46)	**<0.0001**
Peripheral Freezing Counts	-1.19 (-1.94, -0.45)	**0.0039**	-0.40 (-1.11, 0.31)	0.79	-1.29 (-2.05, -0.54)	**0.003**	-0.38 (-1.09, 0.33)	0.76

Table S12. Effect sizes for locomotion and exploration measures across treatment groups compared to pooled geriatric controls. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for each locomotor and exploratory measure in pooled control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Pooled controls served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

Appendix 7.

Overall	Group [Mean (SD)]			Adult-Mid-Age		Adult-Geriatric		Mid-Age-Geriatric	
	Adult (N = 20)	Mid-Age (N = 20)	Geriatric (N = 44)	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	58.50 (6.82)	57.94 (10.17)	46.95 (9.45)	0.06 (-0.56, 0.68)	>0.99	1.31 (0.73, 1.88)	**<0.0001**	1.12 (0.56, 1.69)	**0.0009**
Maximum Running Time (s)	58.50 (6.82)	57.94 (10.17)	46.95 (9.45	0.06 (-0.56, 0.68)	>0.99	1.31 (0.73, 1.88)	**<0.0001**	1.12 (0.56, 1.69)	**0.0009**
Maximum Jumping Distance (cm)	18.80 (4.03)	17.20 (8.38)	13.91 (6.42)	0.15 (-0.47, 0.77)	0.62	0.83 (0.29, 1.38)	**0.0081**	0.35 (-0.19, 0.88)	0.38
Female	Group [Mean (SD)]			Adult-Mid-Age		Adult-Geriatric		Mid-Age-Geriatric	
	Adult (N = 10)	Mid-Age (N = 10)	Geriatric (N = 21)	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	57.78 (7.00)	57.70 (11.08)	47.58 (9.64)	0.01 (-0.87, 0.88)	>0.99	1.12 (0.31, 1.92)	**0.014**	0.97 (0.18, 1.77)	**0.015**
Maximum Running Time (s)	57.78 (7.00)	57.70 (11.08)	47.58 (9.64)	0.01 (-0.87, 0.88)	>0.99	1.12 (0.31, 1.92)	**0.014**	0.97 (0.18, 1.77)	**0.015**
Maximum Jumping Distance (cm)	20.30 (4.47)	17.30 (6.18)	12.43 (6.28)	0.53 (-0.36, 1.42)	0.56	1.33 (0.50, 2.15)	**0.0063**	0.76 (-0.02, 1.54)	0.13
Male	Group [Mean (SD)]			Adult-Mid-Age		Adult-Geriatric		Mid-Age-Geriatric	
	Adult (N = 10)	Mid-Age (N = 10)	Geriatric (N = 23)	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	59.22 (6.93)	58.18 (9.78)	46.38 (9.45)	0.12 (-0.76, 0.99)	0.97	1.42 (0.61, 2.24)	**0.0013**	1.21 (0.41, 2.00)	**0.0033**
Maximum Running Time (s)	59.22 (6.93)	58.18 (9.78)	46.38 (9.45)	0.12 (-0.76, 0.99)	0.97	1.42 (0.61, 2.24)	**0.0013**	1.21 (0.41, 2.00)	**0.0033**
Maximum Jumping Distance (cm)	17.30 (3.06)	17.10 (10.48)	15.26 (6.37)	0.02 (-0.85, 0.90)	>0.99	0.35 (-0.39, 1.10)	0.69	0.23 (-0.51, 0.97)	0.74

Table S1. Group means and effect sizes for treadmill assay measures across age groups. Mean values with standard deviations (SD) are reported for each treadmill assay measure in adult, mid-age, and geriatric crickets (N = number of individuals per group). Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Adults served as the reference group for adult-mid-age and adult-geriatric comparisons, while mid-age served as the reference group for mid-age-geriatric comparisons. Adjusted *P*-values were calculated using Tukey's Honestly Significant Difference (HSD) post-hoc test.

	Adult (N_{Female} = 10, N_{Male} = 10)				Mid-Age (N_{Female} = 10, N_{Male} = 10)				Geriatric (N_{Female} = 21, N_{Male} = 23)			
	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*
	Female	Male			Female	Male			Female	Male		
Maximum Velocity (cm/s)	57.78 (7.00)	59.22 (6.93)	-0.20	>0.99	57.70 (11.08)	58.18 (9.78)	-0.04	>0.99	47.58 (9.64)	46.38 (9.45)	0.12	>0.99

			(-1.09, 0.68)				(-0.92, 0.83)				(-0.47, 0.72)	
Maximum Running Time (s)	57.78 (7.00)	59.22 (6.93)	-0.20 (-1.09, 0.68)	>0.99	57.70 (11.08)	58.18 (9.78)	-0.04 (-0.92, 0.83)	>0.99	47.58 (9.64)	46.38 (9.45)	0.12 (-0.47, 0.72)	>0.99
Maximum Jumping Distance (cm)	20.30 (4.47)	17.30 (3.06)	0.75 (-0.16, 1.66)	0.91	17.30 (6.18)	17.10 (10.48)	0.02 (-0.85, 0.90)	>0.99	12.43 (6.28)	15.26 (6.37)	-0.44 (1.04, 0.16)	0.46

Table S2. Group means and effect sizes for treadmill assay measures comparing sexes within each age group. Mean values with standard deviations (SD) are reported for each treadmill assay measure in adult, mid-age, and geriatric crickets (N = number of individuals per group). Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Females served as the reference group for all comparisons. Adjusted *P*-values were calculated using Bonferroni's multiple comparisons post-hoc test.

	Mean (SD)				
	Control (N = 20)	Acarbose (N = 18)	Rapamycin (N = 20)	Phenylbutyrate (N = 20)	Combined (N = 18)
Maximum Velocity (cm/s)	43.08 (8.22)	46.13 (6.41)	59.98 (6.03)	58.93 (7.09)	55.45 (10.12)
Maximum Running Time (s)	43.08 (8.22)	46.13 (6.41)	59.98 (6.03)	58.93 (7.09)	55.45 (10.12)
Maximum Jumping Distance (cm)	18.10 (8.02)	21.39 (6.62)	21.30 (6.41)	17.00 (8.72)	17.83 (8.34)

Table S3. Group means for treadmill assay measures across treatment groups. Mean values with standard deviations (SD) are reported for each treadmill assay measure in control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets (N = number of individuals per group).

	Control-Acarbose		Control-Rapamycin		Control-Phenylbutyrate		Control-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	-0.40 (-1.05, 0.24)	0.56	-2.30 (-3.10, -1.50)	**<0.0001**	-2.02 (-2.79, -1.26)	**<0.0001**	-1.32 (-2.02, -0.62)	**<0.0001**
Maximum Running Time (s)	-0.40 (-1.05, 0.24)	0.56	-2.30 (-3.10, -1.50)	**<0.0001**	-2.02 (-2.79, -1.26)	**<0.0001**	-1.32 (-2.02, -0.62)	**<0.0001**

Maximum Jumping Distance (cm)	-0.43 (-1.07, 0.21)	0.49	-0.43 (-1.05, 0.20)	0.49	0.13 (-0.49, 0.75)	0.98	0.03 (-0.60, 0.67)	>0.99

Table S4. Effect sizes for treadmill assay measures across treatment groups. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for each treadmill assay measure in control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Controls served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

Female	Mean (SD)				
	Control (N = 10)	Acarbose (N = 10)	Rapamycin (N = 10)	Phenylbutyrate (N = 10)	Combined (N = 8)
Maximum Velocity (cm/s)	41.83 (7.43)	45.40 (6.92)	60.40 (5.95)	56.92 (8.02)	57.52 (8.16)
Maximum Running Time (s)	41.83 (7.43)	45.40 (6.92)	60.40 (5.95)	56.92 (8.02)	57.52 (8.16)
Maximum Jumping Distance (cm)	18.80 (8.40)	19.60 (5.15)	20.50 (3.92)	14.40 (10.06)	20.13 (3.83)
Male	Mean (SD)				
	Control (N = 10)	Acarbose (N = 8)	Rapamycin (N = 10)	Phenylbutyrate (N = 10)	Combined (N = 10)
Maximum Velocity (cm/s)	44.33 (9.17)	47.04 (6.04)	59.57 (6.41)	60.95 (5.72)	53.80 (11.61)
Maximum Running Time (s)	44.33 (9.17)	47.04 (6.04)	59.57 (6.41)	60.95 (5.72)	53.80 (11.61)
Maximum Jumping Distance (cm)	17.40 (8.00)	23.63 (7.87)	22.10 (8.36)	19.60 (6.65)	16.00 (10.56)

Table S5. Group means for treadmill assay measures across treatment groups stratified by sex. Mean values with standard deviations (SD) are reported for each treadmill assay measure in control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated females and males (N = number of individuals per group).

Female	Control-Acarbose		Control-Rapamycin		Control-Phenylbutyrate		Control-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value

Maximum Velocity (cm/s)	-0.48 (-1.37, 0.41)	0.70	-2.64 (-3.84, -1.44)	**<0.0001**	-1.87 (-2.92, -0.82)	**0.0001**	-1.93 (-3.05, -0.80)	**0.0002**
Maximum Running Time (s)	-0.48 (-1.37, 0.41)	0.70	-2.64 (-3.84, -1.44)	**<0.0001**	-1.87 (-2.92, -0.82)	**0.0001**	-1.93 (-3.05, -0.80)	**0.0002**
Maximum Jumping Distance (cm)	-0.11 (-0.99, 0.77)	>0.99	-0.25 (-1.13, 0.63)	0.97	0.45 (-0.43, 1.34)	0.52	-0.19 (-1.12, 0.75)	0.99
<u>**Male**</u>	Control-Acarbose		Control-Rapamycin		Control-Phenylbutyrate		Control-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	-0.32 (-1.26, 0.61)	0.88	-1.84 (-2.89, -0.80)	**0.0001**	-2.08 (-3.17, -0.99)	**<0.0001**	-0.87 (-1.78, 0.05)	**0.027**
Maximum Running Time (s)	-0.32 (-1.26, 0.61)	0.88	-1.84 (-2.89, -0.80)	**0.0001**	-2.08 (-3.17, -0.99)	**<0.0001**	-0.87 (-1.78, 0.05)	**0.027**
Maximum Jumping Distance (cm)	-0.75 (-1.71, 0.21)	0.27	-0.55 (-1.44, 0.34)	0.46	-0.29 (-1.17, 0.59)	0.92	0.14 (-0.79, 1.08)	0.98

Table S6. Effect sizes for treadmill assay measures across treatment groups stratified by sex. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for each treadmill assay measure in control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Controls served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

	Control				Acarbose				Rapamycin			
	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*
	Female	Male			Female	Male			Female	Male		
Maximum Velocity (cm/s)	41.83 (7.43)	44.33 (9.17)	-0.29 (-1.17, 0.59)	>0.99	45.40 (6.92)	47.04 (6.04)	-0.24 (-1.17, 0.69)	>0.99	60.40 (5.95)	59.57 (6.41)	0.13 (-0.75, 1.01)	>0.99
Maximum Running Time (s)	41.83 (7.43)	44.33 (9.17)	-0.29 (-1.17, 0.59)	>0.99	45.40 (6.92)	47.04 (6.04)	-0.24 (-1.17, 0.69)	>0.99	60.40 (5.95)	59.57 (6.41)	0.13 (-0.75, 1.01)	>0.99
Maximum Jumping Distance (cm)	18.80 (8.40)	17.40 (8.00)	0.16 (-0.71, 1.04)	>0.99	19.60 (5.15)	23.63 (7.87)	-0.59 (-1.54, 0.36)	>0.99	20.50 (3.92)	22.10 (8.36)	-0.23 (-1.11, 0.64)	>0.99
	Phenylbutyrate				Combined							
	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*				
	Female	Male			Female	Male						
Maximum Velocity (cm/s)	56.92 (8.02)	60.95 (5.72)	-0.55	>0.99	57.52 (8.16)	53.80 (11.61)	0.35	>0.99				

			(-1.45, 0.34)				(-0.59, 1.28)	
Maximum Running Time (s)	56.92 (8.02)	60.95 (5.72)	-0.55 (-1.45, 0.34)	>0.99	57.52 (8.16)	53.80 (11.61)	0.35 (-0.59, 1.28)	>0.99
Maximum Jumping Distance (cm)	14.40 (10.06)	19.60 (6.65)	-0.58 (-1.48, 0.31)	0.67	20.13 (3.83)	16.00 (10.56)	0.49 (-0.50, 1.49)	>0.99

Table S7. Group means and effect sizes for treadmill assay measures comparing sexes within each treatment group. Mean values with standard deviations (SD) are reported for each treadmill assay measure in control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Females served as the reference group for all comparisons. Adjusted *P*-values were calculated using Bonferroni's multiple comparisons post-hoc test.

Overall	Adult-Control		Adult-Acarbose		Adult-Rapamycin		Adult-Phenylbutyrate		Adult-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	2.00 (1.24, 2.76)	**<0.0001**	1.83 (1.07, 2.58)	**<0.0001**	-0.23 (-0.85, 0.40)	0.96	-0.06 (-0.68, 0.56)	>0.99	0.35 (-0.29, 0.99)	0.61
Maximum Running Time (s)	2.00 (1.24, 2.76)	**<0.0001**	1.83 (1.07, 2.58)	**<0.0001**	-0.23 (-0.85, 0.40)	0.96	-0.06 (-0.68, 0.56)	>0.99	0.35 (-0.29, 0.99)	0.61
Maximum Jumping Distance (cm)	0.11 (-0.51, 0.73)	>0.99	-0.47 (-1.11, 0.18)	0.70	-0.46 (-1.09, 0.17)	0.71	0.26 (-0.36, 0.88)	0.90	0.15 (-0.49, 0.79)	0.99
Female	Adult-Control		Adult-Acarbose		Adult-Rapamycin		Adult-Phenylbutyrate		Adult-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	2.12 (1.02, 3.21)	**<0.0001**	1.70 (0.68, 2.73)	**0.0021**	-0.39 (-1.27, 0.50)	0.91	0.11 (-0.77, 0.99)	>0.99	0.03 (-0.90, 0.96)	>0.99
Maximum Running Time (s)	2.12 (1.02, 3.21)	**<0.0001**	1.70 (0.68, 2.73)	**0.0021**	-0.39 (-1.27, 0.50)	0.91	0.11 (-0.77, 0.99)	>0.99	0.03 (-0.90, 0.96)	>0.99
Maximum Jumping Distance (cm)	0.21 -0.67, 1.09)	0.99	0.14 (-0.74, 1.02)	>0.99	-0.05 (-0.92, 0.83)	>0.99	0.73 (-0.18, 1.63)	0.24	0.04 (-0.89, 0.97)	>0.99
Male	Adult-Control		Adult-Acarbose		Adult-Rapamycin		Adult-Phenylbutyrate		Adult-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	1.75 (0.72, 2.79)	**0.0001**	1.77 (0.67, 2.86)	**0.0049**	-0.05 (-0.93, 0.83)	>0.99	-0.26 (-1.14, 0.62)	0.98	0.54 (-0.35, 1.44)	0.37

Maximum Running Time (s)	1.75 (0.72, 2.79)	**0.0001**	1.77 (0.67, 2.86)	**0.0049**	-0.05 (-0.93, 0.83)	>0.99	-0.26 (-1.14, 0.62)	0.98	0.54 (-0.35, 1.44)	0.37
Maximum Jumping Distance (cm)	-0.02 (-0.89, 0.86)	>0.99	-1.06 (-2.05, -0.07)	0.23	-0.73 (-1.64, 0.18)	0.43	-0.43 (-1.31, 0.46)	0.93	0.17 (-0.76, 1.10)	0.99

Table S8. Effect sizes for treadmill assay measures across treatment groups compared to adults. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for each treadmill assay measure in adult, control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Adults served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

Overall	Mid-Age-Control		Mid-Age-Acarbose		Mid-Age-Rapamycin		Mid-Age-Phenylbutyrate		Mid-Age-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	1.58 (0.87, 2.28)	**<0.0001**	1.34 (0.64, 2.05)	**<0.0001**	-0.24 (-0.86, 0.38)	0.90	-0.11 (-0.73, 0.51)	0.99	0.24 (-0.40, 0.88)	0.82
Maximum Running Time (s)	1.58 (0.87, 2.28)	**<0.0001**	1.34 (0.64, 2.05)	**<0.0001**	-0.24 (-0.86, 0.38)	0.90	-0.11 (-0.73, 0.51)	0.99	0.24 (-0.40, 0.88)	0.82
Maximum Jumping Distance (cm)	-0.11 (-0.73, 0.51)	>0.99	-0.54 (-1.19, 0.11)	0.34	-0.54 (-1.17, 0.09)	0.33	0.02 (-0.60, 0.64)	>0.99	-0.07 (-0.71, 0.56)	>0.99
Female	Mid-Age-Control		Mid-Age-Acarbose		Mid-Age-Rapamycin		Mid-Age-Phenylbutyrate		Mid-Age-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	1.61 (0.60, 2.62)	**0.0002**	1.28 (0.31, 2.24)	**0.0057**	-0.29 (-1.17, 0.59)	0.92	0.08 (-0.80, 0.95)	>0.99	0.02 (-0.91, 0.95)	>0.99
Maximum Running Time (s)	1.61 (0.60, 2.62)	**0.0002**	1.28 (0.31, 2.24)	**0.0057**	-0.29 (-1.17, 0.59)	0.92	0.08 (-0.80, 0.95)	>0.99	0.02 (-0.91, 0.95)	>0.99
Maximum Jumping Distance (cm)	-0.19 (-1.07, 0.68)	0.99	-0.39 (-1.27, 0.50)	0.95	-0.59 (-1.49, 0.30)	0.83	0.33 (-0.55, 1.22)	0.88	-0.51 (-1.45, 0.43)	0.91
Male	Mid-Age-Control		Mid-Age-Acarbose		Mid-Age-Rapamycin		Mid-Age-Phenylbutyrate		Mid-Age-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	1.40 (0.42, 2.38)	**0.0014**	1.27 (0.25, 2.29)	**0.024**	-0.16 (-1.04, 0.72)	>0.99	-0.33 (-1.21, 0.55)	0.92	0.39 (-0.49, 1.28)	0.65
Maximum Running Time (s)	1.40 (0.42, 2.38)	**0.0014**	1.27 (0.25, 2.29)	**0.024**	-0.16 (-1.04, 0.72)	>0.99	-0.33 (-1.21, 0.55)	0.92	0.39 (-0.49, 1.28)	0.65
Maximum Jumping Distance (cm)	-0.03 (-0.91, 0.85)	>0.99	-0.66 (-1.61, 0.29)	0.28	-0.51 (-1.40, 0.39)	0.48	-0.27 (-1.15, 0.61)	0.93	0.10 (-0.83, 1.03)	>0.99

Table S9. Effect sizes for treadmill assay measures across treatment groups compared to mid-aged crickets. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for each treadmill assay measure in mid-age, control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Mid-age crickets served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

Overall	Geriatric-Control		Geriatric-Acarbose		Geriatric-Rapamycin		Geriatric-Phenylbutyrate		Geriatric-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	0.42 (-0.11, 0.95)	0.33	0.09 (-0.46, 0.64)	>0.99	-1.51 (-2.10, -0.92)	**<0.0001**	-1.35 (-1.92, -0.77)	**<0.0001**	-0.87 (-1.44, -0.30)	**0.0017**
Maximum Running Time (s)	0.42 (-0.11, 0.95)	0.33	0.09 (-0.46, 0.64)	>0.99	-1.51 (-2.10, -0.92)	**<0.0001**	-1.35 (-1.92, -0.77)	**<0.0001**	-0.87 (-1.44, -0.30)	**0.0017**
Maximum Jumping Distance (cm)	-0.59 (-1.13, -0.05)	0.15	-1.14 (-1.72, -0.56)	**0.0018**	-1.14 (-1.70, -0.57)	**0.0013**	-0.42 (-0.96, 0.11)	0.43	-0.55 (-1.11, 0.01)	0.23
Female	Geriatric-Control		Geriatric-Acarbose		Geriatric-Rapamycin		Geriatric-Phenylbutyrate		Geriatric-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	0.62 (-0.15, 1.39)	0.30	0.24 (-0.52, 0.99)	0.96	-1.44 (-2.28, -0.61)	**0.0006**	-0.99 (-1.78, -0.20)	**0.021**	-1.04 (-1.90, -0.18)	**0.024**
Maximum Running Time (s)	0.62 (-0.15, 1.39)	0.30	0.24 (-0.52, 0.99)	0.96	-1.44 (-2.28, -0.61)	**0.0006**	-0.99 (-1.78, -0.20)	**0.021**	-1.04 (-1.90, -0.18)	**0.024**
Maximum Jumping Distance (cm)	-0.89 (-1.67, -0.10)	0.11	-1.17 (-1.98, -0.37)	0.052	-1.39 (-2.22, -0.56)	**0.021**	-0.25 (-1.01, 0.51)	0.95	-1.30 (-2.18, -0.42)	0.054
Male	Geriatric-Control		Geriatric-Acarbose		Geriatric-Rapamycin		Geriatric-Phenylbutyrate		Geriatric-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	0.21 (-0.53, 0.96)	0.97	-0.07 (-0.88, 0.73)	>0.99	-1.48 (-2.31, -0.66)	**0.0003**	-1.67 (-2.51, -0.82)	**<0.0001**	-0.71 (-1.48, 0.05)	0.094
Maximum Running Time (s)	0.21 (-0.53, 0.96)	0.97	-0.07 (-0.88, 0.73)	>0.99	-1.48 (-2.31, -0.66)	**0.0003**	-1.67 (-2.51, -0.82)	**<0.0001**	-0.71 (-1.48, 0.05)	0.094
Maximum Jumping Distance (cm)	-0.30 (-1.05, 0.44)	0.93	-1.21 (-2.06, -0.35)	**0.027**	-0.95 (-1.73, -0.18)	0.065	-0.66 (-1.42, 0.10)	0.43	-0.09 (-0.90, 0.71)	>0.99

Table S10. Effect sizes for treadmill assay measures across treatment groups compared to historical geriatrics. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for each treadmill assay measure in historical geriatrics, control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Historical geriatrics served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

Overall	Pooled Control-Acarbose		Pooled Control-Rapamycin		Pooled Control-Phenylbutyrate		Pooled Control-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	-0.04 (-0.57, 0.48)	>0.99	-1.65 (-2.21, -1.09)	**<0.0001**	-1.49 (-2.04, -0.94)	**<0.0001**	-1.02 (-1.57, -0.48)	**0.0001**
Maximum Running Time (s)	-0.04 (-0.57, 0.48)	>0.99	-1.65 (-2.21, -1.09)	**<0.0001**	-1.49 (-2.04, -0.94)	**<0.0001**	-1.02 (-1.57, -0.48)	**0.0001**
Maximum Jumping Distance (cm)	-0.87 (-1.41, -0.33)	**0.0085**	-0.86 (-1.38, -0.34)	**0.0065**	-0.23 (-0.74, 0.27)	0.80	-0.35 (-0.87, 0.18)	0.54
Female	Pooled Control-Acarbose		Pooled Control-Rapamycin		Pooled Control-Phenylbutyrate		Pooled Control-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	0.04 (-0.68, 0.75)	>0.99	-1.67 (-2.47, -0.87)	**<0.0001**	-1.22 (-1.98, -0.46)	**0.0015**	-1.27 (-2.10, -0.45)	**0.0023**
Maximum Running Time (s)	0.04 (-0.68, 0.75)	>0.99	-1.67 (-2.47, -0.87)	**<0.0001**	-1.22 (-1.98, -0.46)	**0.0015**	-1.27 (-2.10, -0.45)	**0.0023**
Maximum Jumping Distance (cm)	-0.71 (-1.44, 0.02)	0.20	-0.86 (-1.60, -0.12)	0.098	0.01 (-0.70, 0.72)	>0.99	-0.79 (-1.59, 0.01)	0.20
Male	Pooled Control-Acarbose		Pooled Control-Rapamycin		Pooled Control-Phenylbutyrate		Pooled Control-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Maximum Velocity (cm/s)	-0.14 (-.92, 0.63)	0.99	-1.55 (-2.33, -0.77)	**<0.0001**	-1.73 (-2.53, -0.93)	**<0.0001**	-0.80 (-1.53, -0.08)	**0.036**
Maximum Running Time (s)	-0.14 (-.92, 0.63)	0.99	-1.55 (-2.33, -0.77)	**<0.0001**	-1.73 (-2.53, -0.93)	**<0.0001**	-0.80 (-1.53, -0.08)	**0.036**
Maximum Jumping Distance (cm)	-1.07 (-1.88, -0.27)	**0.034**	-0.84 (-1.57, -0.11)	0.080	-0.53 (-1.25, 0.18)	0.50	-0.01 (-0.72, 0.70)	>0.99

Table S11. Effect sizes for treadmill assay measures across treatment groups compared to pooled controls. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias for each treadmill assay measure in pooled control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treated crickets. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Pooled controls served as the reference group for all comparisons. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

Appendix 8.

Percent Weight Change	Mean (SD)				
	Control	Acarbose	Rapamycin	Phenylbutyrate	Combined
Overall	7.15 (23.97)	18.96 (28.37)	12.94 (24.23)	13.53 (24.88)	10.30 (23.65)
Female	9.25 (24.33)	29.21 (27.26)	25.78 (24.46)	24.03 (28.75)	18.07 (25.57)
Male	5.83 (24.18)	5.85 (24.67)	2.78 (18.96)	5.13 (17.74)	4.80 (21.02)

Percent Weight Change	[1]Control-Acarbose		Control-Rapamycin		Control-Phenylbutyrate		Control-Combined	
	d (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Overall	0.44 (0.00, 0.89)	0.11	0.24 (-0.20, 0.67)	**0.67**	0.26 (-0.17, 0.69)	**0.59**	0.13 (-0.31, 0.57)	**0.94**
Female	0.75 (0.07, 1.42)	0.039	0.66 (-0.03, 1.36)	0.13	0.54 (-0.15, 1.22)	0.20	0.34 (-0.36, 1.04)	0.65
Male	0.00 (-0.61, 0.61)	>0.99	-0.14 (-0.70, 0.43)	0.98	-0.03 (-0.59, 0.53)	>0.99	-0.04 (-0.61, 0.52)	>0.99

Percent Weight Change	Control	Acarbose	Rapamycin	Phenylbutyrate	Combined
[1]Female [mean (SD)]	9.25 (24.33)	29.21 (27.26)	25.78 (24.46)	24.03 (28.75)	18.07 (25.57)
Male [mean (SD)]	5.83 (24.18)	5.85 (24.67)	2.78 (18.96)	5.13 (17.74)	4.80 (21.02)
d (95% CI)	-0.14 (-0.78, 0.51)	-0.88 (-1.52, -0.23)	-1.05 (-1.69, -0.41)	-0.80 (-1.41, -0.19)	-0.57 (-1.20, 0.07)
Adj. *P*-Value	>0.99	**0.0098**	**0.0089**	**0.042**	0.39

Table S1. Group means and effect sizes for percent weight change across treatment groups. Mean values with standard deviations (SD) are reported for percent weight change in overall and sex stratified control, acarbose, rapamycin, phenylbutyrate, and combined (SLAM)-treatments. Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). [1]Either control or females served as the reference group for all comparisons when appropriate. Adjusted *P*-values were calculated using Dunnett's multiple comparisons post-hoc test.

Appendix 9.

Overall	Group [Mean (SD)]			Adult-Mid-Age		Adult-Geriatric		Mid-Age-Geriatric	
	Adult (N = 19)	Mid-Age (N = 16)	Geriatric (N = 13)	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Percent Weight Change (%)	61.72 (32.63)	-9.45 (20.81)	0.06 (10.23)	2.49 (1.61, 3.38)	**<0.0001**	2.30 (1.40, 3.21)	**<0.0001**	-0.55 (-1.29, 0.20)	0.56
Female	Group [Mean (SD)]			Adult-Mid-Age		Adult-Geriatric		Mid-Age-Geriatric	
	Adult (N = 9)	Mid-Age (N = 9)	Geriatric (N = 8)	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Percent Weight Change (%)	38.38 (20.74)	0.00 (16.35)	-4.45 (9.97)	1.96 (0.83, 3.08)	**0.0003**	2.45 (1.19, 3.71)	**0.0001**	0.31 (-0.65, 1.26)	0.88
Male	Group [Mean (SD)]			Adult-Mid-Age		Adult-Geriatric		Mid-Age-Geriatric	
	Adult (N = 10)	Mid-Age (N = 7)	Geriatric (N = 5)	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Percent Weight Change (%)	82.74 (26.67)	-21.59 (20.52)	7.26 (5.90)	4.06 (2.39, 5.73)	**<0.0001**	3.17 (1.61, 4.73)	**<0.0001**	-1.63 (-2.95, -0.31)	**0.035**

Table S1. Group means and effect sizes for percent weight change across age groups. Mean values with standard deviations (SD) are reported for percent weight change in adult, mid-age, and geriatric crickets overall and stratified by sex (N = number of individuals per group).

Pairwise comparisons are quantified using Cohen’s *d* with Hedges’ *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Adults served as the reference group for adult-mid-age and adult-geriatric comparisons, while mid-age served as the reference group for mid-age-geriatric comparisons. Adjusted *P*-values were calculated using Tukey’s Honestly Significant Difference (HSD) post-hoc test.

	Adult (N_{Female} = 9, N_{Male} = 10)				Mid-Age (N_{Female} = 9, N_{Male} = 7)				Geriatric (N_{Female} = 8, N_{Male} = 5)			
	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*
	Female	Male			Female	Male			Female	Male		
Percent Weight Change (%)	38.38 (20.74)	82.74 (26.67)	-1.76 (-2.82, -0.70)	**<0.0001**	0.00 (16.35)	-21.59 (20.52)	1.12 (0.06, 2.18)	0.091	-4.45 (9.97)	7.26 (5.90)	-1.25 (-2.47, -0.03)	0.87

Table S2. Group means and effect sizes for percent weight change comparing sexes within each age group. Mean values with standard deviations (SD) are reported for percent weight change in adult, mid-age, and geriatric crickets (N = number of individuals per group). Pairwise comparisons are quantified using Cohen’s *d* with Hedges’ *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Females served as the reference group for all comparisons. Adjusted *P*-values were calculated using Bonferroni’s multiple comparisons post-hoc test.

Overall							
Day	Group	N	Passed (N, %)	Failed (N, %)	Relative Risk (95% CI)	p-value	Adjusted p-value
1	Geriatric	16	1 (6.25)	15 (93.75)	Reference	–	–
	Mid-Age	19	7 (36.84)	12 (63.16)	5.89 (0.81, 42.99)	0.047	0.094
	Adult	20	9 (45.00)	11 (55.00)	7.20 (1.02, 51.05)	0.022	0.044
2	Geriatric	14	5 (35.71)	9 (64.29)	Reference	–	–
	Mid-Age	19	11 (57.89)	8 (42.11)	1.62 (0.73, 3.61)	0.296	0.592
	Adult	20	18 (90.00)	2 (10.00)	2.52 (1.23, 5.17)	0.002	0.004
3	Geriatric	14	6 (42.86)	8 (57.14)	Reference	–	–
	Mid-Age	18	15 (83.33)	3 (16.67)	1.94 (1.03, 3.68)	0.027	0.054
	Adult	20	20 (100)	0 (0)	2.28 (1.24, 4.18)	0.0002	0.0004
4	Geriatric	14	7 (50.00)	7 (50.00)	Reference	–	–
	Mid-Age	18	16 (88.89)	2 (11.11)	1.78 (1.03, 3.08)	0.022	0.044
	Adult	20	20 (100)	0 (0)	2.00 (1.15, 3.31)	0.0006	0.0012
5	Geriatric	14	8 (57.14)	6 (42.86)	Reference	-	-
	Mid-Age	18	18 (100)	0 (0)	1.70 (1.07, 1.70)	0.0033	0.0066
	Adult	20	20 (100)	0 (0)	1.71 (1.08, 2.70)	0.0022	0.0044

Table S3. Daily escape paradigm success rates and effect size comparisons across age groups. For each experimental day, escape performance was reported for adult, mid-age, and geriatric crickets as the number and percentage of individuals that successfully completed the paradigm versus those that failed (N = number of individuals per group; % = percentage of group). Between-group comparisons were conducted using χ^2 analysis or Fisher's exact test, as appropriate. Effect sizes were expressed as relative risk (RR) with corresponding 95% confidence interval (CI) in the format (lower, upper). Adjusted *P*-values were calculated using the Bonferroni correction.

Female							
Day	Group	N	Passed (N, %)	Failed (N, %)	Relative Risk (95% CI)	p-value	Adjusted p-value
1	Geriatric	8	1 (12.50)	7 (87.50)	Reference	–	–
	Mid-Age	10	4 (40.00)	6 (60.00)	3.20 (0.44, 23.28)	0.314	0.628
	Adult	10	5 (50.00)	5 (50.00)	4.00 (0.58, 27.71)	0.152	0.304
2	Geriatric	7	3 (42.86)	4 (57.14)	Reference	–	–
	Mid-Age	10	5 (50.00)	5 (50.00)	1.17 (0.41, 3.36)	>0.99	>0.99
	Adult	10	9 (90.00)	1 (10.00)	2.10 (0.87, 5.06)	0.101	0.202
3	Geriatric	7	3 (42.86)	4 (57.14)	Reference	–	–
	Mid-Age	10	8 (80.00)	2 (20.00)	1.87 (0.75, 4.64)	0.162	0.324
	Adult	10	10 (100)	0 (0)	2.22 (0.93, 5.28)	0.015	0.029
4	Geriatric	7	4 (57.14)	3 (42.86)	Reference	–	–
	Mid-Age	10	8 (80.00)	2 (20.00)	1.40 (0.69, 2.85)	0.593	>0.99
	Adult	10	10 (100)	0 (0)	1.67 (0.87, 3.21)	0.051	0.102
5	Geriatric	7	5 (71.43)	2 (28.57)	Reference	-	-
	Mid-Age	10	10 (100)	0 (0)	1.33 (0.82, 2.17)	0.154	0.308
	Adult	10	10 (100)	0 (0)	1.33 (0.82, 2.17)	0.154	0.308
Male							
Day	Group	N	Passed (N, %)	Failed (N, %)	Relative Risk (95% CI)	p-value	Adjusted p-value
1	Geriatric	8	0 (0)	8 (100)	Reference	–	–
	Mid-Age	9	3 (33.33)	6 (66.67)	5.67 (0.33, 97.32)	0.206	0.412
	Adult	10	4 (40.00)	6 (60.00)	6.80 (0.42, 111.18)	0.092	0.184
2	Geriatric	7	0 (0)	7 (100)	Reference	–	–
	Mid-Age	9	6 (66.67)	3 (33.33)	10.00 (0.66, 151.41)	0.011	0.022
	Adult	10	9 (90.00)	1 (10.00)	13.50 (0.92, 198.05)	0.0004	0.0008
3	Geriatric	7	2 (28.57)	5 (71.43)	Reference	–	–
	Mid-Age	8	7 (87.50)	1 (12.50)	3.06 (0.92, 10.17)	0.041	0.082
	Adult	10	10 (100)	0 (0)	3.33 (1.03, 10.84)	0.0034	0.0068
	Geriatric	7	3 (42.86)	4 (57.14)	Reference	–	–

4	Mid-Age	8	8 (100)	0 (0)	2.20 (0.92, 5.25)	0.026	0.052
	Adult	10	10 (100)	0 (0)	2.22 (0.93, 5.28)	0.015	0.029
5	Geriatric	7	3 (42.86)	4 (57.14)	Reference	-	-
	Mid-Age	8	8 (100)	0 (0)	2.20 (0.92, 5.25)	0.026	0.052
	Adult	10	10 (100)	0 (0)	2.22 (0.93, 5.28)	0.015	0.029

Table S4. Daily escape paradigm success rates and effect size comparisons across age groups stratified by sex. For each experimental day, escape performance was reported for adult, mid-age, and geriatric crickets as the number and percentage of individuals that successfully completed the paradigm versus those that failed (N = number of individuals per group; % = percentage of group). Between-group comparisons were conducted using χ^2 analysis or Fisher's exact test, as appropriate. Effect sizes were expressed as relative risk (RR) with corresponding 95% confidence interval (CI) in the format (lower, upper). Geriatrics served as the reference group for all comparisons. Adjusted *P*-values were calculated using the Bonferroni correction.

	Group	N	Passed (N, %)	Failed (N, %)	Relative Risk (95% CI)	p-value
Geriatric	Male	7	3 (42.86)	4 (57.14)	Reference	–
	Female	7	5 (71.43)	2 (28.57)	1.67 (0.63, 4.42)	0.592
Mid-Age	Male	8	8 (100)	0 (0)	Reference	–
	Female	10	10 (100)	0 (0)	1.01 (0.82, 1.26)	>0.99
Adult	Male	10	10 (100)	0 (0)	Reference	–
	Female	10	10 (100)	0 (0)	1.00 (0.83, 1.21)	>0.99

Table S5. Overall escape paradigm success rates and effect size comparisons comparing sexes within each age group. Escape performance was reported for adult, mid-age, and geriatric crickets as the number and percentage of individuals that successfully completed the paradigm versus those that failed (N = number of individuals per group; % = percentage of group). Between-group comparisons were conducted using χ^2 analysis or Fisher's exact test, as appropriate. Effect sizes were expressed as relative risk (RR) with corresponding 95% confidence interval (CI) in the format (lower, upper). Males served as the reference group for all comparisons.

Overall	Group [Mean (SD)]			Adult-Mid-Age		Adult-Geriatric		Mid-Age-Geriatric	
	Adult (N = 19-20)	Mid-Age (N = 17-19)	Geriatric (N = 16)	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Main Trial									
Decision Making Time (s)	9.15 (2.75)	20.54 (10.07)	11.96 (4.45)	-1.53 (-2.24, -0.82)	**<0.0001**	-0.76 (-1.44, -0.08)	0.32	1.05 (0.34, 1.75)	**0.0064**
Time to Punishment Arm (s)	12.50 (6.15) 19	23.34 (12.33) 17	14.65 (6.63)	-1.11 (-1.91, -0.41)	**0.0016**	-0.33 (-1.00, 0.34)	0.75	0.85 (0.14, 1.56)	**0.018**
Time to Reward Arm (s)	8.54 (2.61)	19.61 (10.64)	10.93 (3.71)	-1.42 (-2.12, -0.71(	**<0.0001**	-0.74 (-1.42, -0.06)	0.38	1.03 (0.32, 1.74)	**0.014**
Test Trial									
Decision Making Time (s)	13.73 (5.45)	26.25 (16.89)	16.11 (11.48)	-0.99 (-1.65, -0.32)	**0.0084**	-0.26 (-0.89, 0.37)	>0.99	0.69 (0.03, 1.34)	**0.012**
Time to Punishment Arm (s)	13.26 (7.91)	24.99 (27.87)	12.39 (4.80)	-0.57 (-1.21, 0.07)	0.50	0.13 (-0.53, 0.78)	>0.99	0.59 (-0.09, 1.27)	0.53

Time to Reward Arm (s)	14.19 (6.22)	27.52 (14.30)	13.27 (5.92)	-1.20 (-1.88, -0.51)	**0.0063**	0.15 (-0.51, 0.81)	>0.99	1.23 (0.51, 1.96)	**0.0010**

Table S6. Group means and effect sizes for decision-making measures across age groups. Mean values with standard deviations (SD) are reported for each decision-making measure in adult, mid-age, and geriatric crickets (N = number of individuals per group). Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Adults served as the reference group for adult-mid-age and adult-geriatric comparisons, while mid-age served as the reference group for mid-age-geriatric comparisons. Adjusted *P*-values were calculated using Tukey's Honestly Significant Difference (HSD) post-hoc test.

Female	Group [Mean (SD)]			Adult-Mid-Age		Adult-Geriatric		Mid-Age-Geriatric	
	Adult (N = 9-10)	Mid-Age (N = 9-10)	Geriatric (N = 8)	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Main Trial									
Decision Making Time (s)	9.05 (2.31)	20.97 (10.29)	12.64 (5.19)	-1.53 (-2.53, -0.53)	**0.0008**	-0.89 (-1.86, 0.08)	0.51	0.94 (-0.04, 1.92)	**0.034**
Time to Punishment Arm (s)	11.47 (5.15)	22.38 (10.25)	16.20 (7.65)	-1.28 (-2.30, -0.27)	**0.034**	-0.70 (-1.68, 0.28)	0.53	0.64 (-0.33, 1.62)	0.34
Time to Reward Arm (s)	8.48 (2.48)	20.39 (11.54)	11.28 (4.37)	-1.37 (-2.34, -0.39)	**0.0010**	-0.78 (-1.74, 0.19)	0.67	0.95 (-0.03, 1.93)	**0.021**
Test Trial									
Decision Making Time (s)	12.09 (4.66)	24.04 (17.18)	14.45 (6.07)	-0.91 (-1.83, 0.01)	**0.046**	-0.42 (-1.36, 0.52)	0.89	0.68 (-0.28, 1.63)	0.16
Time to Punishment Arm (s)	11.22 (5.62)	25.47 (33.84)	13.59 (6.21)	-0.56 (-1.46, 0.33)	0.18	-0.38 (-1.32, 0.55)	0.96	0.44 (-0.50, 1.38)	0.34
Time to Reward Arm (s)	12.97 (7.05)	22.61 (9.96)	15.31 (7.27)	-1.07 (-2.01, -0.13)	0.066	-0.31 (-1.25, 0.62)	0.86	0.78 (-0.18, 1.75)	0.24
Male	Group [Mean (SD)]			Adult-Mid-Age		Adult-Geriatric		Mid-Age-Geriatric	
	Adult (N = 10)	Mid-Age (N = 8-9)	Geriatric (N = 8)	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value	*d* (95% CI)	Adj. *P*-Value
Main Trial									
Decision Making Time (s)	9.25 (3.25)	20.06 (10.43)	11.28 (3.87)	-1.37 (-2.37, -0.37)	**0.0031**	-0.55 (-1.49, 0.40)	0.80	1.03 (0.02, 2.05)	**0.028**
Time to Punishment Arm (s)	13.43 (7.07)	24.42 (14.99)	13.10 (5.49)	-0.93 (-1.91, 0.05)	**0.034**	0.05 (-1.11, 0.80)	>0.99	0.95 (-0.09, 1.98)	**0.039**
Time to Reward Arm (s)	8.60 (2.86)	18.73 (10.16)	10.58 (3.18)	-1.33 (-2.33, -0.34)	**0.0071**	-0.63, (-1.58, 0.32)	0.82	1.00 (-0.01, 2.01)	**0.049**
Test Trial									
Decision Making Time (s)	15.36 (5.93)	28.72 (17.23)	11.21 (1.98)	-1.01 (-1.97, -0.06)	**0.028**	0.85 (-0.12, 1.82)	0.70	1.31 (0.26, 2.36)	**0.005**
Time to Punishment Arm (s)	15.30 (9.56)	24.45 (21.41)	11.18 (2.74)	-0.54 (-1.45, 0.38)	0.50	0.53 (-0.42, 1.48)	0.88	0.80 (-0.19, 1.79)	0.28
Time to Reward Arm (s)	15.42 (5.35)	32.98 (16.87)	11.23 (3.59)	-1.37 (-2.37, -0.37)	**0.0005**	0.86 (-0.12, 1.83)	0.62	1.64 (0.54, 2.74)	**<0.0001**

Table S7. Group means and effect sizes for decision-making measures across age groups stratified by sex. Mean values with standard deviations (SD) are reported for each decision-making measure in juvenile, adult, and geriatric crickets (N = number of individuals per group). Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Adults served as the reference group for adult-mid-age and adult-geriatric comparisons, while mid-age served as the reference group for mid-age-geriatric comparisons. Adjusted *P*-values were calculated using Tukey's Honestly Significant Difference (HSD) post-hoc test.

	Adult (N_{Female} = 9-10, N_{Male} = 10)				Mid-Age (N_{Female} = 9-10, N_{Male} = 8-9)				Geriatric (N_{Female} = 8, N_{Male} = 8)			
	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*	Mean (SD)		*d* (95% CI)	*P*
	Female	Male			Female	Male			Female	Male		
Main Trial												
Decision Making Time (s)	9.05 (2.31)	9.25 (3.25)	-0.07 (-0.94, 0.81)	>0.99	20.97 (10.29)	20.06 (10.43)	0.08 (-0.82, 0.98)	>0.99	12.64 (5.19)	11.28 (3.87)	0.28 (-0.70, 1.27)	>0.99
Time to Punishment Arm (s)	11.47 (5.15)	13.43 (7.07)	-0.30 (-1.21, 0.61)	>0.99	22.38 (10.25)	24.42 (14.99)	-0.15 (-1.11, 0.80)	>0.99	16.20 (7.65)	13.10 (5.49)	0.44 (-0.55, 1.43)	>0.99
Time to Reward Arm (s)	8.48 (2.48)	8.60 (2.86)	-0.04 (-0.92, 0.83)	>0.99	20.39 (11.54)	18.73 (10.16)	0.15 (-0.76, 1.05)	>0.99	11.28 (4.37)	10.58 (3.18)	0.17 (-0.81, 1.15)	>0.99
Test Trial												
Decision Making Time (s)	12.09 (4.66)	15.36 (5.93)	-0.59 (-1.48, 0.31)	>0.99	24.04 (17.18)	28.72 (17.23)	-0.26 (-1.16, 0.64)	>0.99	14.45 (6.07)	11.21 (1.98)	0.68 (-0.33, 1.69)	>0.99
Time to Punishment Arm (s)	11.22 (5.62)	15.30 (9.56)	-0.50 (-1.39, 0.39)	>0.99	25.47 (33.84)	24.45 (21.41)	0.03 (-0.87, 0.93)	>0.99	13.59 (6.21)	11.18 (2.74)	0.47 (-0.52, 1.47)	>0.99
Time to Reward Arm (s)	12.97 (7.05)	15.42 (5.35)	-0.37 (-1.26, 0.51)	>0.99	22.61 (9.96)	32.98 (16.87)	-0.73 (-1.65, 0.20)	0.061	15.31 (7.27)	11.23 (3.59)	0.67 (-0.33, 1.68)	>0.99

Table S8. Group means and effect sizes for decision-making measures comparing sexes within each age group. Mean values with standard deviations (SD) are reported for each decision-making measure in adult, mid-age, and geriatric crickets (N = number of individuals per group). Pairwise comparisons are quantified using Cohen's *d* with Hedges' *g* correction to account for small sample size bias. Effect sizes are reported alongside 95% confidence intervals (CI) in the format (lower, upper). Females served as the reference group for all comparisons. Adjusted *P*-values were calculated using Bonferroni's multiple comparisons post-hoc test.