Calx, a sodium/calcium exchanger, may affect lifespan in *Drosophila melanogaster*

Jung-Wan Mok¹, Hyunglok Chung¹,² and Kwang-Wook Choi¹§

¹Department of Biological Sciences, Korea Advanced Institute of Science and Technology, Daejeon 34141, Korea
²Current address: Department of Molecular and Human Genetics, Baylor College of Medicine, Houston, TX 77030, USA

§Correspondence to: Kwang-Wook Choi (kchoi100@kaist.ac.kr (mailto:kchoi100@kaist.ac.kr))
Calcium homeostasis is essential for normal body function. Calx is a *Drosophila* homolog of the mammalian sodium/calcium exchanger (NCX) involved in the regulation of intracellular calcium (Ca$^{2+}$) level (Schwarz and Benzer 1997). A major function of Calx is to export excess Ca$^{2+}$ to the outside of the cell when intracellular Ca$^{2+}$ level is elevated (Hryshko *et al.* 1996). Genetic studies in *Drosophila* have shown that Calx mutants can develop to adult flies, even though Calx is expressed throughout the developmental stages (Wang *et al.* 2005). However, Ca$^{2+}$ efflux mediated by Calx is crucial for maintaining the cellular Ca$^{2+}$ homeostasis in light-activated sensory neurons (Wu *et al.* 2011). In addition to its role for phototransduction, Calx is also required for preventing light-induced retinal degeneration caused by Ca$^{2+}$ overload (Wang *et al.* 2005).

Thus far, Calx function has been extensively studied in the retinal cells. However, expression of Calx gene is not restricted to the eye, and potential functions of Calx in other tissues are largely unknown. Interestingly, disrupted
Restricted to the eye, and potential functions of Calx in other tissues are largely unknown. Interestingly, disrupted Ca\(^{2+}\) homeostasis has been implicated in aging and is regarded as one of the biomarkers of aging (Foster and Kumar 2002). Although mammalian NCXs have been implicated in aging of tissues and organs (Gomez-Villafuertes et al. 2007; Zhang et al. 2014), it remains to be studied whether NCXs are important for animal lifespan. Here, we address the question whether Calx affects lifespan in fly.

To determine whether Calx is required for normal lifespan, we carried out genetic analysis using two Calx mutants, Calx\(^A\) and Calx\(^B\). It has been shown that homozygous Calx\(^A\) and Calx\(^B\) mutant flies are viable (Wang et al. 2005). Calx\(^A\) mutants have a point mutation (T822I) but show relatively normal level of protein expression in adult head. In contrast, Calx\(^B\) is a regulatory mutation that causes reduced protein expression (Wang et al. 2005). To check whether such mutant effects can also be seen in non-head tissues, we examined Calx protein expression in whole adult fly body. It has been reported that Calx is expressed as a single 110 kD protein in adult head and body (Wang et al., 2005). \(w^{1118}\) flies used as wild-type control showed a major band at 110 kD and a weaker band at 120 kD (Fig. 1A). Consistent with earlier studies (Wang et al. 2005), we found a strong reduction in the 110 kD band in Calx\(^B\) mutant, while Calx\(^A\) mutant showed a nearly indistinguishable pattern from wild-type. Calx\(^B\) mutant showed severe reduction in both 110 and 120 kD bands, suggesting that Calx exists at least in two different forms in adult fly.

Next, we measured lifespan of wild-type and Calx males. We used isogenic \(w^{1118}\) as control since it was previously used as control for analyzing Calx mutant phenotypes in phototransduction (Wang et al. 2005). In our lifespan assay at 25 °C, both Calx\(^A\) and Calx\(^B\) mutants showed considerable reduction in the survival rate compared with the wild-type control (Fig. 1B). Median lifespan of Calx\(^A\) and Calx\(^B\) mutants was 24 and 21.5 days, respectively, whereas the median for wild-type was about 36 days (Fig. 1D). We also examined survival rates of Calx mutants at 29 °C (Fig. 1C). At this high temperature, wild-type flies showed a lower survival rate with median lifespan of 21.5 days. Under this condition, Calx\(^A\) mutant flies had a significantly shorter median lifespan than Calx\(^B\) mutant (12.5 days for Calx\(^A\); 17.7 days for Calx\(^B\)) (Fig. 1D). Since Calx\(^A\) encodes a mutated protein, it is possible that the mutant Calx protein might be more unstable at 29 °C, causing more severe phenotype in longevity. Alternatively, Calx\(^A\) mutant cells may require a higher rate of calcium extrusion at the upper extreme of their viable temperature range than their more normal growth temperature (25 °C). We also checked the lifespan of transheterozygotes for Calx\(^A\) and Calx\(^B\) mutations (Calx\(^A\)/Calx\(^B\)). Trans-heterozygous flies also showed significantly reduced lifespan compared with wild-type, indicating that Calx\(^A\) and Calx\(^B\) fail to complement the longevity phenotype. Consistent with the hypomorphic nature of the Calx\(^B\) allele, trans-heterozygous flies showed an intermediate lifespan between Calx\(^A\) and Calx\(^B\) mutants (Fig. 1C, D). Taken together, our data suggest that the Calx mutations are responsible for the observed phenotype of shorter longevity. These results are preliminary, and to rule out potential genetic background effects, additional controls should be included in the future.

This study raises a possibility that Calx might be required for normal lifespan. The Ca\(^{2+}\) influx channel TRP, which has an opposite function to Calx, is crucial for phototransduction (Montell 2005; Wang et al. 2005). The trp gene
has an opposite function to Calx, is crucial for phototransduction (Montell 2005; Wang et al. 2005). The trp gene has a paralog, trp-like (trpl) (Phillips et al. 1992). Although there is no strict paralog of Calx in Drosophila, Nckx30C is a distant relative of Calx (Haug-Collet et al. 1999). It remains to be tested whether these related genes are also required for normal lifespan. Importantly, retinal degeneration by loss of TRP or constitutive TRP function can be suppressed by defects or overexpression of Calx, respectively. Further studies are necessary to see whether lifespan is dependent on the functional relationship between Calx and TRP in the intracellular Ca\(^{2+}\) regulation, although such genetic analysis may be complicated by the existence of related genes like trpl and Nckx30C. It is also an intriguing question whether NCX homologs of Calx play a role in lifespan of mammals.

**Methods**

**Western Blot** – For western blot experiment, 10 adult male flies for each genotype (3 days old virgin) were used for protein extraction in 200\(\mu\)l of SDS sample buffer. After boiling for 5 minutes at 94 °C, samples were centrifuged at 12000g for 10 minutes. Supernatants were loaded on 10% polyacrylamide gel. Fractionated proteins were transferred by western blotting for immunostaining (Calx antibody 1:1000, kind gift from Dr. Craig Montell).

**Lifespan assay** – For lifespan assay, one hundred adult male flies of each genotype (1 day old, virgin) were collected by minimal exposure to carbon dioxide gas. Flies were raised in food vials (10 males/vial) and transferred to new vials every 2-3 days. Number of dead flies was recorded every day. Statistical significance of the data from lifespan assay was determined by P-value evaluation from two-tailed T test.

**Reagents**

**Fly strains** – Isogenized w\(^{118}\) (#5905), Calx\(^{A}\) (#24496) and Calx\(^{B}\) (#24497) mutants were kindly provided by the Bloomington Drosophila Stock Center.

**Funding**

This research was supported by grants (NRF-2014K1A1A2042982 and NRF-2017R1A2B3007516) of the National Research Foundation of Korea funded by the Ministry of Education, Science & Technology, Republic of Korea.

**Author Contributions**

Jung-Wan Mok: Data curation, Formal analysis, Investigation, Methodology, Validation, Writing - original draft, Writing - review and editing, Visualization

Hyunglok Chung: Resources, Supervision

Kwang-Wook Choi: Funding acquisition, Project administration, Supervision, Writing - review and editing.
Acknowledgments
We thank Craig Montell for Calx antibody and Bloomington stock center for fly stocks. We also thank Kyung-Ok Cho for discussions.

Reviewed By
Steven Marygold and Anonymous

History
Received: January 3, 2020
Accepted: February 7, 2020
Published: February 12, 2020

References
10.1177/107385840200800404 | PubMed

10.1007/s12035-007-0007-0 | PubMed

10.1083/jcb.147.3.659 | PubMed

10.1085/jgp.108.1.67 | PubMed


Copyright
© 2020 by the authors. This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International (CC BY 4.0) License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.