Kank Is an EB1 Interacting Protein that Localises to Muscle-Tendon Attachment Sites in *Drosophila*

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**Abstract**

Little is known about how microtubules are regulated in different cell types during development. EB1 plays a central role in the regulation of microtubule plus ends. It directly binds to microtubule plus ends and recruits proteins which regulate microtubule dynamics and behaviour. We report the identification of Kank, the sole *Drosophila* orthologue of human Kank proteins, as an EB1 interactor that predominantly localises to embryonic attachment sites between muscle and tendon cells. Human Kank1 was identified as a tumour suppressor and has documented roles in actin regulation and cell polarity in cultured mammalian cells. We found that *Drosophila* Kank binds EB1 directly and this interaction is essential for Kank localisation to microtubule plus ends in cultured cells. Kank protein is expressed throughout fly development and increases during embryogenesis. In late embryos, it accumulates to sites of attachment between muscle and epidermal cells. A kank deletion mutant was generated. We found that the mutant is viable and fertile without noticeable defects. Further analysis showed that Kank is dispensable for muscle function in larvae. This is in sharp contrast to *C. elegans* in which the Kank orthologue VAB-19 is required for development by stabilising attachment structures between muscle and epidermal cells.

**Introduction**

Microtubules are dynamic polar polymers that perform vital functions in eukaryotic cells. The microtubule network constantly alters its dynamics and organisation according to the requirements of the cell, for example forming the spindle during cell division and forming a network which structurally supports the cell. These changes are mainly regulated by proteins that interact with microtubules, collectively called microtubule-associated proteins (MAPs) [1]. MAPs are a wide range of proteins with diverse structures and functions. So far, it has been a challenge to identify the molecular basis of tissue specific microtubule dynamics and organisation during development.

A subset of MAPs associate with growing ends of microtubules. EB1 is highly conserved from humans to yeast and has been shown to be necessary for dynamics at plus-ends [2,3]. This protein was originally identified as a binding partner of APC (adenomatous polyposis coli) [4] and was later shown to track growing microtubule plus ends in cells [5]. It has been shown that EB1 plays a central role in regulation at microtubule plus ends [6], as it can bind microtubule plus ends directly [7] and can recruit various proteins with a range of structures and functions. Two sequence motifs have been identified which mediate the interaction with EB1, namely the CAP-Gly domain and the SxIP motif [8–10].

Although many studies on EB1 have been carried out in cultured cells, understanding of the roles and actions of EB1 are limited in the context of the whole organism. EB1 may regulate microtubule plus end behaviour differently in different cell types, as it recruits cell type specific effectors to microtubule plus ends. Systematic identification of EB1 interacting proteins has been carried out using mass-spectrometry [10,11], but the choice of starting materials limits which proteins can be identified. Identification of EB1-interacting proteins differentially expressed in different tissues, such as muscle and the epidermis, will be a key step to determining how microtubule ends are regulated in different cell types.

In this study we identify the sole *Drosophila* orthologue of human Kank1–4 as an EB1-interacting protein, found to localise predominantly at sites of muscle-tendon attachment. The conserved protein Kank1 was identified as a human tumour suppressor [12], though exactly how it suppresses tumour growth remains unclear. So far, investigation of the mammalian Kank proteins has been carried out primarily in cell culture and they have been shown to have roles in inhibition of actin nucleation, actin organisation [13,14], cell polarity [15] and cell growth [16]. A study in *C. elegans* shows that the sole Kank orthologue, VAB-19, localises to epidermal attachment structures between muscle and epidermal cells in developing nematode embryos, and later at circumferential bands that cover the length of the worm [17]. Disruption of VAB-19 during development is lethal, likely...
Kank: A Novel EB1 Interactor in Drosophila

Kank is a novel EB1-interacting protein with a specific localisation during embryogenesis. We demonstrate that Kank interacts with EB1 in S2 cells and requires EB1 for localisation to microtubule ends. Furthermore, we show that this interaction with EB1 is through an SxIP motif present in Kank. Additionally, we establish that Kank is expressed at most stages of the Drosophila lifecycle and its expression increases during embryonic development. Complete deletion of Kank coding sequence from the genome shows that expression increases during embryonic development. Complete deletion of the genomic region between the two FRT sites [23] which are located at either side of the coding sequence of kank, Flippase was expressed in transheterozygotes carrying both transposons to induce recombination between the two FRT sites (Figure 4A,B) and recombination events which produce the deletion of the genomic region between the two FRTs were selected for. This resulted in 3 strains in which the entire Kank-
coding sequence was deleted (kankD1, kankD2, kankD3). Deletion of expected regions was confirmed by PCR (Figure S3), and the absence of the Kank protein was confirmed by western blotting (Figure 4D–G). Unexpectedly, unlike C. elegans in which mutation of the kank orthologue, vab-19, is lethal, the kank deletion was homozygous viable and fertile, therefore a homozygous...
Viability was confirmed at 18°C and 29°C.

To detect the Kank protein in cells or cell extracts, we have generated antibodies which recognise the Kank protein. To establish when Kank is expressed during development, total protein samples from 21–24 hours old embryos, third instar larvae, early pupae, late pupae and adult flies were prepared. All samples were analysed by western blotting using an affinity purified Kank antibody against Kank(489–900) (Figure 4C–G). A band around 160 kDa, which may represent a set of proteins with slightly different mobility, was detected in all developmental stages in wild type. A weak band around 140 kDa is also visible, possibly representing either a degradation product or an alternative isoform of Kank. These bands were not present in protein samples prepared from the kank deletion mutant at the equivalent stages, confirming that these bands correspond to the Kank protein.

These results indicate that Kank is expressed throughout the lifecycle of the fly.

Kank localises to muscle-tendon attachment sites in Drosophila embryos

To determine if Kank protein levels change throughout embryogenesis, embryos were collected for 3 hours and aged for various lengths at 25°C. Protein samples from these embryos were
analysed by western blotting using the Kank antibody (Figure 5A).

The Kank bands were not visible in 0–3 hour old embryos, suggesting little or no maternal contribution. The 160 kDa band was visible from 3 hours after egg laying (AEL) and increased in intensity as the embryos age, until roughly 15–18 hours which is equivalent to the stages 16/17 of embryo development (Figure 5A). The smaller band becomes visible 15–18 hours AEL. These bands are absent in the \textit{kank} deletion mutant. This expression pattern during development indicates that expression of Kank may be temporally regulated during embryogenesis.

To determine the localisation of Kank in embryos, wild-type embryos of various ages were immunostained with our Kank antibody and with the monoclonal antibody 22c10 which recognises the Map1b-like protein Futsch and highlights neurons [24]. In embryos at stages 16/17 or later, Kank showed very clear, distinct localisation (Figure 5B). Each hemi segment (half segment) distinctly displays eight spots of Kank signal, arranged as four spots in a line along the ventral-lateral axis and four parallel spots in a line along the dorsal-lateral axis, the posterior most spots are shifted dorsally. These signals were not observed in the \textit{kank} deletion embryos (Figure 5B), confirming that they represent Kank localisation.
Figure 4. Kank is expressed throughout development but is dispensable for viability and fertility. (A) kank (CG10249) is a ~27 kb gene found at 51D2 on chromosome arm 2R. Putative isoforms are shown. Those in black are likely to be expressed while those in grey are less likely to be expressed based on ModEncode data. The cDNA clone GH03482 that we used in our analysis represents isoform A of kank (highlighted in blue). This isoform lacks the KN motif found in other Kank proteins (shown in purple). (B) Kank was deleted using transposons containing FRT sites. Firstly, the appropriate two transposons flanking the Kank coding sequence were introduced in trans positions on homologous chromosomes (i). A flippase was induced to promote recombination between the FRT sites (ii) and generated a deletion of the intervening sequence (iii) (C) The fragment of Kank(489–900) used for generating an antibody against the Kank protein. (D–G) The Kank antibody detected the endogenous protein in all lifecycle stages examined by immunoblotting in wild type but not in Kank deletion mutants. Kank was detected in embryos 21–24 hrs after egg laying (D), in 3rd instar larvae (E), in male and female late pupae [= L] and early pupae of undetermined gender [= E] (F), and in both male and female adult flies (G).

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The position of the signal appears to coincide with sites at which muscle and tendon cells attach [25]. Co-staining of Kank with β-3 tubulin, which is preferentially expressed in muscle cells, confirmed that Kank is localised at muscle-tendon attachment sites (Figure 5C).

Closer observation revealed that the Kank signal overlaps with microtubules and is strongly concentrated near sites where microtubule ends are attached to the periphery of muscle cells (Figure 6A). It is unclear whether the Kank signal is in muscle or tendon cells. This localisation was confirmed when embryos were co-stained for Kank and actin (Figure S4). As Kank protein localises at sites of muscle attachment to epidermal cells, the muscle morphology and microtubule organisation was examined using the β3-tubulin antibody. No clear differences were observed between wild type and the Kank deletion mutant (Figure 6B).

Additionally, we tested muscle and sensory function in larvae using a wide range of assays (Figure S5) and surprisingly did not find any significant differences between kankΔ mutant and wild-type larvae, despite the specific localisation of the protein.

**Discussion**

EB1 is a key protein which regulates microtubule plus ends through the recruitment of other proteins [6,21]. In this study, we have identified Kank as an interacting protein of EB1 using *in vitro* expression cloning. We have shown that Kank localises to microtubule plus ends in an EB1-dependent manner in culture cells. Kank is predominantly localised to the attachment region of muscle and epidermal cells in late embryos. Flies completely

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**Figure 5.** Kank localises to muscle-tendon attachment sites in late stage *Drosophila* embryos. (A) The ~160 kDa Kank band was detected in embryos from 3–6 hours after egg laying (AEL). The amount of Kank detected by immunoblotting was observed to increase during embryonic development. The ~140 kDa band becomes apparent 15–18 hours AEL. (B) An antibody against Kank(489–900) stained a distinct pattern in stage 16/17 embryos. This staining was not observed in kank deletion mutants. The 22c10 antibody, which highlights neurons, was used to orient embryos. (C) β3-tubulin staining reveals the structure of microtubules in somatic muscle cells. Co-staining with the Kank antibody showed that Kank localises at sites of muscle attachment to the epidermis. (D) A schematic of *Drosophila* embryonic somatic musculature with sites of Kank staining indicated. Scale bars = 25 μm.

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lacking Kank are viable and fertile, and show no defects in muscle or sensory function in our assays.

Here we used in vitro expression cloning to identify EB1 interacting proteins. As the annotated cDNA collection used here has been derived from various developmental stages and tissues and each gene is represented only once, we rationalised that this approach would identify EB1-interacting proteins in an unbiased way regardless of the expression levels in particular cell types. Kank, the sole Drosophila orthologue of the human tumour suppressor Kank1, was identified. This data indicates that Kank may have a role in linking actin and microtubule regulation during development.

Interaction between EB1 and Kank is shown by in vitro pull down experiment and colocalisation in S2 cells. RNAi of EB1 in GFP-Kank transfected S2 cells demonstrates that EB1 is required for microtubule plus end localisation of Kank. We further showed that an EB1 interaction motif (SxIP motif) of Kank is essential for its localisation to microtubule plus ends in S2 cells. This sequence is conserved among Drosophila and consensus sequences are present in human Kank1 and Kank4. A recent proteomic study identified Kank2 as a putative EB1 binding protein, though this was not confirmed by other methods [10]. It would be of future interest to see whether the mammalian and C. elegans Kank orthologues associate with microtubules or with EB1.

We have also demonstrated that Kank, like human Kank1, has the capacity to localise to the nucleus and likely does so transiently. Using truncations, we identified the N-terminus and the C-terminus as regions of Kank which can localise to the nucleus while truncations of Kank which contain the middle region do not. Treatment of S2 cells with leptomycin-B has shown that GFP-Kank shuttles between the cytoplasm and the nucleus, at least in a minority of cells. Human Kank1 has been shown to accompany the transport of β-catenin from the cytoplasm to the nucleus in some cell types [26] and it is possible this function is conserved in Drosophila.

Deletion of the kank coding region reveals that Kank is dispensable for viability and fertility in Drosophila. This is in contrast with what was observed in C. elegans, where disruption of VAB-19 expression was fatal. Additionally, we found that, despite the developmental disorders observed in humans [27,28], Drosophila kank larvae do not display any motility or muscular defects.

Kank is present throughout the Drosophila life cycle and its expression increases during embryogenesis. At late embryonic stages, the pattern of Kank localisation coincides with muscle-tendon attachment sites in developing embryos. How this localisation of Kank relates to the function of the protein has yet to be determined. In C. elegans, GFP-VAB-19 localises to muscle-epidermal attachment structures, consistent with the localisation observed for Kank and is essential to maintain myotactin, VAB-10A and intermediate filaments at attachment sites [17]. Drosophila does not contain any cytoplasmic intermediate filaments [29], often substituting arrays of microtubules in their place [30]. The Drosophila homologue of myotactin, sidekick,
functions in cell adhesion at synapses in the retina [31] but its function in muscles has not been examined. Shot, the *Drosophila* homologue of VAB-10A, has been demonstrated to be required in tendon cells for muscle-tendon junction formation [32]. It is required for the localisation of EB1 and actin-microtubule interaction in these cells [33,34]. Interestingly, Shot also displays a similar localisation to Kank in the late stages of embryogenesis [25]. Specifically, Shot localises to the area enriched in microtubule ends in tendon cells [34]. Given the role of mammalian Kank proteins in actin regulation, it would be of future interest to test functional interactions between Kank and Shot in *Drosophila*. In humans it has been shown that an isoform of human Kank1 has higher expression in adult skeletal muscle, liver, heart, kidney and tissues in other tissues, though no studies of embryonic tissues exist [35].

We have generated a complete deletion of Kank coding sequence. Flies lacking Kank are viable and fertile, and our wide range of assays did not identify defects in muscle activities in a third instar larva. It is possible that our assays were not sensitive enough to detect the specific function of Kank. Considering the localisation of Kank in *Drosophila* embryos, it may have a specific function in interaction between muscle and epidermal cells. Alternatively, the Kank function may be masked by a redundancy with other proteins, for example Shot or other EB1 interacting proteins. It will be interesting to further uncover such muscle specific EB1 interacting proteins and determine the intricate complexes formed at the site of muscle-tendon attachment.

**Materials and Methods**

**Identification of Kank/CG10249 as an EB1 interactor**

Kank was identified by *Drosophila* in vitro expression cloning. A pool of 24 cDNAs from an annotated collection of *Drosophila* cDNAs was transcribed and translated *in vitro* in the presence of 35S-methionine (Easytag, Perkin Elmer) using the T7 TnT Quick Coupled system (Promega). Each translated product was split into two and incubated in DIVEC buffer (50 mM Heps pH 7.6, 1 mM MgCl₂, 1 mM EGTA, 200 mM NaCl, 0.5% Triton-X100) for 60 minutes with amylase resin (New England Biolabs) coupled with bacterially-produced MBP or MBP-EB1. After extensive washing in DIVEC buffer, the beads were boiled with the sample buffer and run on an SDS gel. Dried gels were exposed to X-ray film (Hyperfilm, GE Healthcare). cDNA pools which gave bands with amylose resin (New England Biolabs) coupled with bacterially-produced MBP or MBP-EB1. After extensive washing in DIVEC buffer, the beads were boiled with the sample buffer and run on an SDS gel. Dried gels were exposed to X-ray film (Hyperfilm, GE Healthcare). cDNA pools which gave bands were further studied by testing with other proteins, for example Shot or other EB1 interacting proteins. It will be interesting to further uncover such muscle specific EB1 interacting proteins and determine the intricate complexes formed at the site of muscle-tendon attachment.

**Drosophila Techniques**

Standard *Drosophila* techniques were used throughout [39] and w1118 was used as wild type in this study. *kankΔ* mutants were generated by inducing, by heat shock, recombination between two FRT-containing transposons (PBac{PB}e00393 and PBac{WH}f01478). Recombination resulted in a loss of the w gene from both transposons upon deletion of the *kank* gene. Chromosomes which have lost the w gene were selected for and tested over a deficiency uncovering the *kank* gene. No chromosomes lethal over the deficiency were isolated. Chromosomes were

**Molecular and Protein Techniques**

Standard DNA and protein techniques were used throughout [36]. The *kank* coding region (GH03482) was introduced first into the Gateway entry vector pDONR221 and then into destination vector, pAGW to generate a plasmid for expression of Kank fused to GFP at the N-terminal under the actin5C promoter. Regions of *kank* were amplified using the appropriate primers which facilitated the addition of *attB* sites, allowing introduction of the *kank* regions into the appropriate vectors. To mutate the EB1 binding motif in Kank, in two single nucleotide substitutions were introduced. To mutate amino acid 764 (I→N) nucleotide 2339 of GH03482 was mutated (T→A) using the following primer pair (forward/reverse), CGGCGGACTCGAGGAAATTCGCGAGCCAAGC and GCT-GTGGGTCCGGGATTTCTCAGTCTCCGGC. To mutate amino acid 765 (P→K) nucleotides 2341 and 2342 of GH03482 were mutated (CC→AA) using the following primer pair (forward/reverse), CCGTCGAGACGGTTAATAGCGACCCAGCGC and GAGTGCTGTTGGTGCTATTTCTCAGT-CCGACGG using Quick Change XLII site directed mutagenesis kit (Agilent), following manufacturer’s instructions. Antibodies against Kank (1:100) and mouse anti-α-tubulin 1:1000 (DM1A, Sigma) were used for western blotting and detected by the ECL system (Amersham Biosciences) according to the manufacturer’s protocols.

**Antibody Generation**

Rabbit antibodies were raised to MBP-Kank(489–900) in the following way: Purified protein (250 µg) was injected at regular intervals. The final bleed from each antibody was used for antibody purification by a method using antigen immobilised on nitrocellulose membrane [37]. 20 µg of purified antigen was run on an SDS gel and transferred onto a nitrocellulose membrane. The membrane was stained with 1% Ponceau S in 1% acetic acid and the band of antigen excised. The band was washed and blocked and the antibody was then bound to the antigen by incubating the membrane in 100 µl of the final antiserum diluted 1:10 in blocking solution overnight at 4°C. After extensive washes in washing buffer, the antibody was eluted by three, consecutive 30 seconds washes with 400 µl elution buffer (50 mM glycine-HCl pH2.3, 0.5 M NaCl, 0.5% Tween 20, 100 µg/ml BSA, 0.1% NaN₃). All of the eluates were combined and immediately neutralised by adding Na₂HPO₄ solution to a final concentration of 50 mM. The affinity purified antibodies were tested for specificity and optimal dilution in immunoblotting and immuno-fluorescence experiments. Antibodies were stored at 4°C.

**Cell culture**

*Drosophila* Schneider S2 cells were cultured. Transfections and RNA interference (RNAi) were performed according to published methods [38]. Plasmids were transfected using Effectene transfection reagent (Qiagen) following manual’s instructions. Double-stranded RNA (dsRNA) corresponding to regions amplified by primer pairs (forward/reverse), CGACCTACTATAGG-GAGATGCCCGTGCTGTTGGCAC and CGACCTACTATAGGGAGATGCCCGTGCTGTTGGCAC for EB1 were used. dsRNA corresponding to *E. coli* beta-lactamase was used as a control.

**Cytological Analysis**

S2 cells were plated on Concanaavalin A coated coverslips for 2–3 hours and fixed with 90% methanol, 3% formaldehyde, 5 mM NaHCO₃ pH 9 at −80°C. Cells were stained with the following primary antibodies: rabbit anti-Kank(489–900) 1:20, rabbit anti-EB1 1:200, mouse anti-α-tubulin 1:250 (DM1A, Sigma), rabbit anti-GFP 1:500 (Molecular Probes), mouse anti-GFP 1:500 (3E6, Molecular Probes). Cells were visualised with an Axioplan-2 fluorescence microscope (Zeiss) and images were recorded with an attached CCD camera (Hamamatsu), controlled by OpenLab 2.2.1 software (Perkin Elmer). Images were processed using ImageJ.
tested over the deficiency for the presence of the kank genomic region by PCR to confirm deletion of the region (Table S1).

Embryo collection and staining
Embryos were collected on plates and aged appropriately. Embryos were then washed with deionised water and dechorionated in 2.5% chloros in water. For Kank/22c10 and Kank/Actin stained embryos: Embryos were washed thoroughly and transferred to a glass vial containing 1:1 heptane: methanol. The vial was sealed and shaken for 1 minute after which the liquid was extracted with a pipette and replaced with fresh methanol. These embryos were then incubated at room temperature for over 4 hours. Relydration was done by passaging the embryos through increased concentrations of PBS in methanol (20%, 40%, 60%, 80% 100%) for 10 minutes at a time and stained. For Kank/Bβ-tubulin stained embryos: embryos were stained according to previously published methods [40]. Antibody concentrations used were: 1:500 rabbit anti-Kank (489–900), 1:500 mouse 22c10 (Developmental Hybridoma Studies Bank), 1:5000 guinea pig anti-Bβ tubulin [41] and 1:500 rabbit anti-Bβ tubulin [12]. Embryos were then mounted in mounting medium (2.5% propyl gallate, 85% glycerol) and viewed on an LSM510 confocal microscope. Images were processed using ImageJ.

Supporting Information
Figure S1 Kank(1–889) and Kank(489–1224), co-localise with EB1. S2 cells transfected with GFP-Kank(1–889) and GFP-Kank(489–1224) were co-stained for GFP and EB1. The number of cells with GFP localised to the majority of the EB1 comets (> 50% estimate) was counted. For both truncations colocalisation of the GFP signal with EB1 was observed in the majority of observed cells. Error bars show the standard error of the mean. (TIF)

Figure S2 Kank(1–500), Kank(489–900) or Kank(889–1224) do not co-localise with EB1. S2 cells were transfected with Kank(1–500), Kank(489–900) or Kank(889–1224) and co-stained for GFP and EB1. These truncations showed diffuse localisation within the cytoplasm. In addition, Kank(1–500) and Kank(889–1224) localised to the nucleus. GFP signal was observed at the cell periphery for Kank(1–500) and Kank(489–900). Yellow boxes are areas magnified in images shown below. Scale bars = 5 µm. (TIF)

Figure S3 Deletion of Kank was confirmed by PCR. (A) PCR was carried out on genomic DNA of three kank deletion (A1, A2, A3) and two parental lines (P[c00393], P[01478]) using designated primers (Table S1). (TIF)

Figure S4 Kank localises to muscle tendon attachment sites. As actin staining is quite ubiquitous, Z sections of actin stained embryos were examined to visualise cells which resembled those muscle cells indicated in the schematic. The localisation of the Kank signal is observed at the sites of muscle-tendon attachment. Coloured boxes show the similarities between actin staining and the somatic muscle schematic. Scale bar = 25 µm. (TIF)

Table S1 Sequences of primers used to check for kank deletion in genomic DNA.

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Author Contributions
Conceived and designed the experiments: SMRC NSD HO. Performed the experiments: SMRC NSD. Analyzed the data: SMRC NSD HO. Contributed reagents/materials/analysis tools: SMRC NSD HO. Contributed to the writing of the manuscript: SMRC NSD HO.

References

Figure S5 kankΔ larvae do not exhibit any motility or sensory defects. Unless otherwise stated, larvae examined were late 3rd instar (~76 hours after hatching) and significance was determined by Student’s t-test (A–C,E) or Fisher’s exact chi-square test (D,F). Error bars show the standard error of the mean (A–C,E) or the 95% confidence interval (D,F). All assays were carried out at room temperature. (A) In the first assay the motility of larvae was examined (adapted from [43]) The number of gridlines passed by individual larva in 60 seconds was counted. The number of gridlines crossed by the kankΔ larvae was similar to that crossed by the wild type control (p>0.05). (B) In the second assay the overall coordination and motility of larvae was then examined by counting the number of full body motile waves (peristaltic waves) carried out by larvae in one minute (adapted from [44]). The peristaltic waves travelled the entire length of the larva in a coordinated fashion in both wild type and the mutant. The frequency of peristaltic waves was not significantly different between the kankΔ and wild type (p>0.05). (C) In the third assay, larvae were rolled from their ventral to their dorsal side while on an agarose plate (adapted from [45]). The time taken for them to right themselves was measured, with a maximum of 2 minutes allowed. The time taken by kankΔ and wild type was similar (~30 seconds; p>0.05). (D) The fourth assay determined if larvae maintained burrowing ability. Foraging third instar larva were placed on top of food in a bottle which was then placed in the dark for 2 hours (adapted from [46]). After this time, the number of larvae remaining on the food was counted. No significant difference between the kankΔ and the wild-type larvae were observed (p>0.05). (E) Larvae were manually stimulated to elicit a nociceptive response (adapted from [47]). Third instar larvae was prodded by a blunt instrument at their abdominal segments and evading action was observed. No significant difference was found between kankΔ and wild type (p>0.05). The number of stimulations required to elicit a response was similar between strains. (F) kankΔ larvae have a wild type reaction to light (adapted from [48]). Foraging 3rd instar larvae were placed on the midline of a plate with food. Half the plate was covered with aluminium foil and the plate was placed under a strong lamp in an otherwise dark room. Larvae were allowed to wander for 45–60 minutes after which the number on each side of the plate was counted. kankΔ larvae show an aversion to light equal to that of wild type. (TIF)


