**Title:** GDF15 knockout does not impact maternal food intake or body composition but increases female offspring bodyweight in the first 14 days of life

**Authors:** Molly C. Mulcahy, Noura El Habbal, JeAnna R. Redd, Haijing Sun, Randy Seeley Brigid E. Gregg, Dave Bridges

**Affiliations:**

**Keywords:**

**Author contribution:** MM, NEH, and DB conceived of experiments. Data were collected by MM, NEH, JRR, and HS. RS provided the experimental animals. MM carried out analysis and wrote the initial draft of the manuscript. All authors contributed to the editing of the manuscript and approved its final format before publication.

Corresponding Author:

Dave Bridges, PhD, Email address: [davebrid@umich.edu](mailto:davebrid@umich.edu), Postal address: 1863 SPH I 1415 Washington Heights, Ann Arbor, Michigan 48109-2029, Telephone: +1 (734) 764-1266

**Journals:**

# Abstract

# Introduction

# Materials and Methods:

## Animal Husbandry and Protocol

Animals were housed in a temperature and humidity-controlled facility with a 12-hour light:dark cycle. Male and female *Gdf15* null animals were generated by the Seeley lab as detailed in (Frikke-Schmidt et al., 2019). Null animals were generated using CRISPR Cas-9 deletion of Exon 2 of Gdf15. Exon 2 (translational start site), which we ablated, is present in every GDF15 transcript.

## Genotyping

At 14 days of age, a small section of the tail was collected and digested in 100uL of lysis buffer (10 mM Tris (pH8.0), 150 mM NaCl, 10 mM EDTA, 0.1% SDS and 1 mg/ml proteinase K) at 55°C for 4 hours. Digested DNA sample was utilized with DreamTaq Green to generate PCR product (ThermoFisher Scientific, Catalog #K1081). Genotyping by PCR was conducted with 2 forward and one reverse primer sets (forward 1: 5' GAT TCC CGC CCG AAT TAG C 3', forward 2: 5' CCG AAT TAG CCT GGT CAC CC 3', Reverse: 5’ ATC CGT CCT ACT CTG GCT AAG 3'). Initiation of PCR was at 95 °C for 3 minutes, followed by 38 cycles of denaturation(95°C for 30 seconds), annealing (60°C for 40 seconds), and elongation (72°C for 1 minute), and a final amplification step at 72°C for 5 minutes. PCR product was put through gel electrophoresis on a 2% agarose gel at 130V and imaged on a gel documentation system using UV light. PCR product resulted in 2 visible bands, one at 200bp *Gdf15-/-* and another at 600bp *Gdf15+/+.* Mice with both bands were considered *Gdf15+/-*.

## Mating

*Gdf15* is highly expressed in placental tissue during mouse pregnancy (REF). We chose to study *Gdf15+/+* mated pairs compared to *Gdf15-/-* pairs because comparing littermates of *Gdf15+/-* pairs would result in placental contribution of *Gdf15* to dam serum (**Figure 1A**). Our primary outcome of concern was maternal food intake, for dam serum levels of *Gdf15* to reflect the genetic knockout, we combined homozygous genotype mating pairs, resulting in homogenous genotype progeny and placenta (**Figure 1B**). Adult female mice (GDF15-/-n=8, GDF15+/+n=6), at least 70 days old, were singly housed with *ad libitum* access to water and a standard chow diet (CD, Picolab Laboratory Rodent diet 5L0D; 5% of Calories from fat, 24% from protein, 71% from carbohydrates). Once single-housed, weekly food intake and body weight measurements began and continued throughout the experiment. After one week of food and body weight monitoring, males of like-genotype for *Gdf15* were introduced into the dam’s cage. Males were allowed to remain in the breeding cage until a copulatory plug was discovered, indicating pregnancy (E0.5). Body weight and food intake measurements continued weekly through gestation and postnatal day 14.5. Their resultant offspring and their placentae were homozygous *Gdf15+/+ Gdf15-/-* and were studied until postnatal day 14 (PND14). All protocols were approved by the institutional animal care and use committee of the University of Michigan.

## Insulin tolerance test

On E16.5, dams underwent insulin tolerance testing (Bridges et al., 2022). Dams were placed in clean cage without access to food but with ad libitum access to water at ZT 2. Dams were fasted for 6 hours (ZT2-ZT8). Baseline blood glucose was assessed using a tail clip and a handheld glucometer (OneTouch Ultra). After initial blood glucose measurement, an intraperitoneal injection of insulin was administered (Humulin, u-100; 0.75U/kg lean mass). Blood glucose was measured in 15-minute intervals for 2 hours. Area under the curve was calculated by taking the sum of all glucose values for each animal and averaging by genotype. 24 hours after ITT, we collected two fed blood samples: at ZT1 and ZT13. Dams were lightly anesthetized via inhaled isoflurane and whole blood was collected by retroorbital bleed in a heparinized capillary tube. Blood was allowed to clot on ice for 20 minutes then was spun down in a cold centrifuge (4°C, Eppendorf microcentrifuge, model 5415R) for 20 minutes at 2000 g. Serum was decanted off after centrifugation and stored at -80°C until used for analysis.

*Serum Gdf15 Quantification*

Serum *Gdf15* analysis was completed using maternal serum collected 24 hours after ITT. Gdf15 levels were determined via ELISA according to manufacturer guidelines (R&D system, catalog # MGD150).

## Offspring

Pups were counted and body weights were recorded within 24 hours of birth, postnatal day (PND 0.5). Gestational age was determined as difference between birth dates and dates of appearance of copulatory plug. At PND 3.5, litter sizes were culled to 2 male and 2 female pups, to standardize amount of nutrition provided to each pup. Survival of pups to PND 3.5 was assessed by comparing the number of pups present at PND 3.5 to the number present on PND 0.5 and is expressed as a percentage. Body weight was assessed for each pup on PND 0.5, 3.5, 7.5, 10.5, and 14.5. Pups were euthanized by decapitation on the 2 hours before milk collection began (PND 14.5-17.5).

## Weigh-suckle-weigh, milk volume production

On postnatal day 10.5, we assessed milk volume production by the weigh-suckle-weigh method (ref). Dams were weighed using an analytical scale to the nearest 0.01 gram and placed in a clean cage with free access to food and water. Pups were then weighed in aggregate and placed in a clean cage on top of a heating pad without access to food or water. Dam and pups remained separated for 2 hours. After 2 hours, weight measurements were repeated, and pups were reintroduced to the dam’s cage where they remained for 1 hour. After one hour, the final weights were taken for both dams and pups in aggregate. Volume of milk produced is expressed the average weight lost by each dam after 1 hour of nursing divided by the number of pups in the litter.

## Milk collection

Milk collection took place on PND 14.5-17.5. Pups were separated from dams and sacrificed 2 hours before milk collection began. Dams were allowed to *ad libitum* access to food and water in a clean cage during that time. Dams were anesthetized with intramuscular injection of Ketamine/Xylazine (0.1275g/kg body weight) into forelimb muscle. Once the dam was fully anesthetized, an oxytocin injection (2U per dam) was given in the forelimb muscle to begin let-down. Milk was collected with a pipette after manually expressing milk from nipples and stored in a 1.5 mL Eppendorf tube. Following milk collection, dams were immediately euthanized via isoflurane inhalation and cervical dislocation. Mammary glands were dissected.

## Milk fat percentage determination

Whole milk was collected from dams at Postnatal day 14.5-17.5 and was stored at -80° C until analyzed. Whole milk was thawed on wet ice then homogenized by pipetting up and down. Milk was then diluted in PBS+EDTA in a 1:3 ratio and mixed thoroughly by pipetting up and down.

Capillary tubes were filled with the diluted milk solution and one end was double-sealed with crit-o-seal. Sample tubes were spun in 8 consecutive 120-second cycles in a mini hematocrit spinner (Iris Sample Processing, StatSpin CritSpin M961-122). In the capillary after 16 total minutes of spinning, total fat and aqueous layers were visible. These layers were measured using a 150mm dial caliper (General Tools, 6” Dial Caliper). Percentage of milk fat was determined with based on total volume of diluted milk sample. Milk samples were analyzed in duplicate, or triplicate if milk fat percentage differed by more than 25% in the first two samples.

## Statistical Analyses

Data were analyzed in R Studio version4.2.0 (R Core Team, 2021) and are represented as mean ± standard error. Longitudinal analyses, such as food intake, body composition, and insulin tolerance testing were assessed using linear mixed effects modeling using R package Lme4 (Bates et al., 2015) with random effect of mouse ID and dam and fixed effects of genotype, age, and sex. Models of offspring body weight were assessed using a two-way ANOVA for sex and genotype, with an interaction between the two. If a significant interaction was observed, sex-stratified models were then used and the p-value for the interaction was reported. Otherwise, sex was used as a covariate in a non-interacting model. Pairwise values were assessed for normality by the Shapiro-Wilk test and equivalence of variance by Levene’s test. Variables that were not normally distributed or of equivalent variance underwent non-parametric testing via Mann-Whitney U test. Those that were normally distributed and of equivalent variance were assessed via Student’s t-test. P-values <0.05 were considered statistically significant.

# Results

## Maternal Body Weight and Food Intake Is Similar During Perinatal Period

To assess the role of *Gdf15* ablation in maternal food intake and body composition during mouse pregnancy, we mated *Gdf15+/+* dams with *Gdf15+/+* males and compared them to *Gdf15-/-* mated pairs. Body weight and food intake were measured weekly, beginning one week before mating until pups reached 14 days of age.

Daily maternal food intake was similar in the prenatal period between genotypes with *Gdf15-/-*dams consuming 2.18 kcals less per day than*Gdf15+/+* counterparts (p=0.23). Food intake increased over the course of gestation by 0.202 kcal per gestational day (p=0.00076). This resulted in a 6.46% lower cumulative food intake in *Gdf15-/-*dams during the course of their pregnancies that was not statistically significant (p=0.302)

## Postnatal body Weight differs, but food intake does not

Body weight weight was similar in *Gdf15-/-* was 1.62 grams greater than *Gdf15+/+* dams in the postnatal period (p=0.20). Despite differences in postnatal body weight for -/- dams, food intake was only 1.13 kcal per day lower in -/- dams during the postnatal period, which was not significantly lower than the +/+ dams (p=0.79), but tended to decreased by 0.87 kcal per day after parturition(p=0.032).

## Gdf15-/- dams normal insulin tolerance during pregnancy

On Gestational day 16.5, we conducted an intraperitoneal insulin tolerance test to assess the effect of Gdf15 ablation on maternal insulin sensitivity during pregnancy. Fasting blood glucose was 13.46% lower in *Gdf15-/-* dams compared to *Gdf15+/+* dams (pgeno=0.20). Linear mixed effect modeling of the experiment revealed a significant and expected effect of time (duh), and an average of 6.37 mg/dL lower glucose values in -/- dams (pgeno=0.71). This was confirmed by -/- having comparable areas under the curve, only 5.22% lower than +/+ counterparts (p=0.74). The initial rate of drop of blood glucose was 9.34% lower in -/- dams compared to +/+ dams (p=X.XX).

# Conclusion

# Discussion

# 

# References

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, *67*, 1–48. https://doi.org/10.18637/jss.v067.i01

Bridges, D., Mulcahy, M. C., & Redd, J. R. (2022, March 7). *Insulin Tolerance Test*. Protocols.Io. dx.doi.org/10.17504/protocols.io.b5zxq77n

Frikke-Schmidt, H., Hultman, K., Galaske, J. W., Jørgensen, S. B., Myers, M. G., & Seeley, R. J. (2019). GDF15 acts synergistically with liraglutide but is not necessary for the weight loss induced by bariatric surgery in mice. *Molecular Metabolism*, *21*, 13–21. https://doi.org/10.1016/j.molmet.2019.01.003

R Core Team. (2021). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. https://www.R-project.org/