Supplementary material for Trumble et al. "Successful hunting increases testosterone and cortisol in a subsistence population"

Provisioning and Signaling Models (Bootstrap Statistical Models)

Because sample sizes were relatively small, additional bootstrapped regression models (500 repetitions) were conducted to examine provisioning and signaling models. Bootstrapped regression models controlling for age^2, BMI and time hunting find that hunters returning with large kills did not differ from men who killed smaller game in absolute (p=0.48) or percent change in testosterone (p=0.12) at the time of the kill, nor in absolute or percent change in testosterone upon returning home (p=0.95, p=0.99 respectively). Absolute log cortisol (β=0.36, p=0.008) and percent change in cortisol (β=54.22, p=0.001) were higher for men killing a larger animal at the time of the kill, but not upon returning home (p=0.47, p=0.24, respectively) controlling for age^2, BMI and time hunting. Regression models also find no evidence of differences in absolute (p=0.88) or change in testosterone (p=0.84) for successful hunters who encountered individuals other than their nuclear family on the way home, or at their house (p=0.95, p=0.93), controlling for age^2, BMI and time hunting. Identical models examining audience effect on absolute cortisol and cortisol change find no differences during the return trip (p=0.41, p=0.94), or later at home (p=0.81, p=0.56). No bootstrap models differed from regression models in significance or beta sign.

The Dual Hormone Hypothesis Supplement

The Dual Hormone Hypothesis (DHH) suggests that interactions between cortisol and testosterone regulate dominance and aggression in human males [1], specifically that high testosterone phenotypes pursue aggressive or dominant strategies while cortisol is low, but that high baseline cortisol negates the behavioral effects of high testosterone. Males facing considerable stressors (indicated by high cortisol) should reduce aggressive behavior to avoid the energetic costs and physical danger associated with male-male competition [2].

As all of the men in our study were hunting, we cannot attest to any associations between testosterone, cortisol, and behavioral state (e.g. aggression, dominance, or competitive intent), and can only examine changes in testosterone during the course of the hunt.

Although aggressive behaviors may be down regulated for males in poor condition, there are theoretical reasons to believe that males should maintain the ability to produce rapid increases in testosterone regardless of baseline condition or cortisol [3]. Acute increases in testosterone allow muscle tissue to uptake sugars more rapidly [4]. Regardless of baseline cortisol, an increase in testosterone would benefit muscle tissues, enhancing performance for any male in a competitive or aggressive situation. Previous research among the Tsimane shows that despite significantly lower baseline testosterone levels when compared to US males, Tsimane men still maintain a similar relative increase in testosterone when engaged in male-male competition [5]. Males of many seasonally breeding species produce large increases in testosterone while under social and energetic stress during the mating season [3].

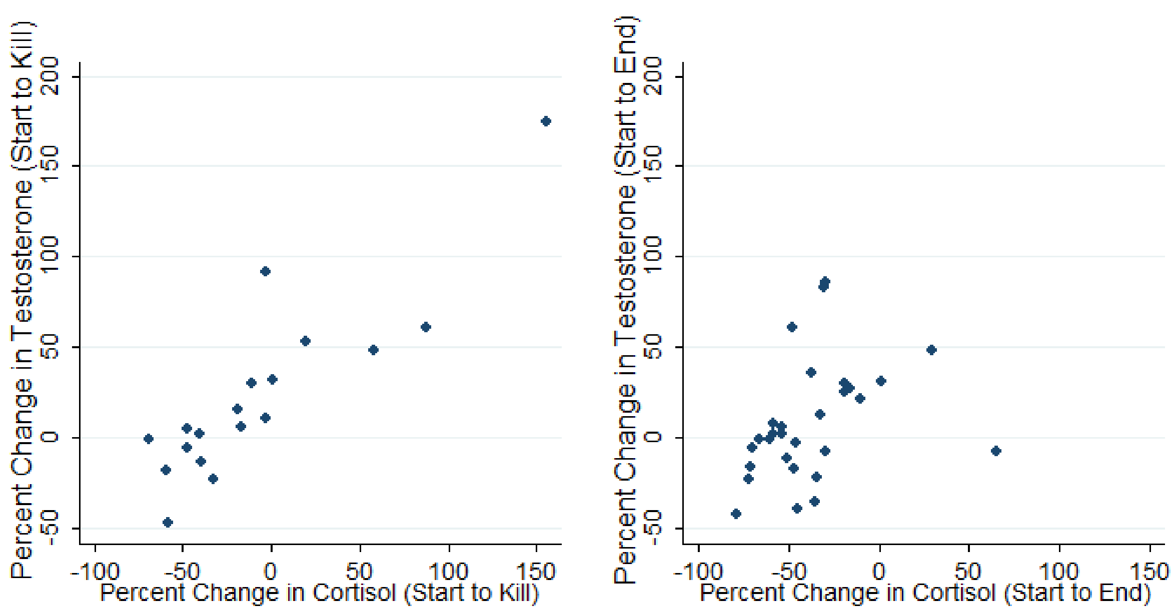
The primary analyses from the original study examining the DHH [1] split individuals into high and low baseline testosterone and high and low baseline cortisol, using one standard deviation above and below the mean as cutoffs. In our sample, no individuals were both in the high testosterone and low cortisol subgroup (no individuals were one SD above the mean for testosterone and one SD below the mean for cortisol) as in our study, baseline cortisol and testosterone trended towards a positive correlation (r=.34, p=0.056), see supplemental figure 1.

Because we could not recreate the primary DHH analysis, we instead conducted regression analyses examining the percent change in testosterone with age^2, BMI, time hunting, baseline testosterone and baseline cortisol, and an interaction term between testosterone and cortisol as covariates. For individuals that returned with meat, the percent change in testosterone at the end of the day was not modified by interactions between baseline cortisol and testosterone ($p=0.51$). Likewise, hunters not returning with meat showed no evidence that the percent change in testosterone was affected by interactions between cortisol and testosterone ($p=0.28$). Previous studies find evidence for an interaction between pre-competition testosterone and cortisol only for men in a defeat condition, but not in the victory condition [1].

We also conducted additional regression analyses examining the role of the baseline testosterone-to-cortisol ratio in predicting the percent change in testosterone. Regression models examining how the testosterone-to-cortisol ratio impacted percent change in testosterone (with age^2, time hunting, and BMI as covariates), showed no evidence that the testosterone-to-cortisol ratio played any role in percent change in testosterone from the beginning to the end of the hunt ($p=0.19$).

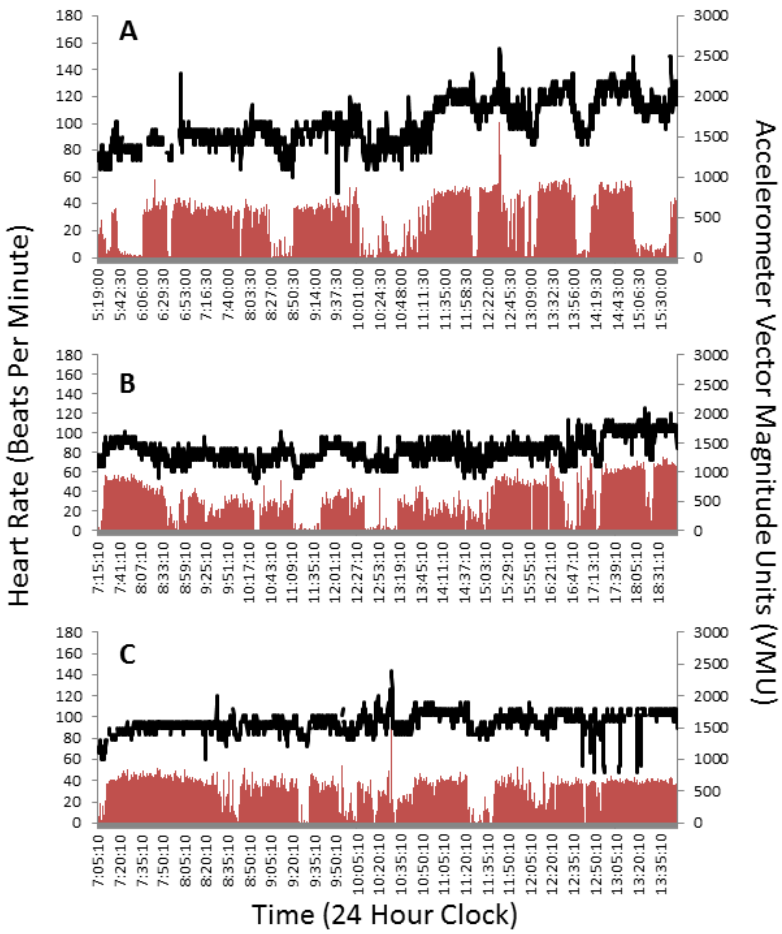
Although we find no evidence for the DHH in this study, it should be noted that the original and subsequent DHH studies examined how cortisol and testosterone could interact to affect dominance behavior. Our results with regard to hunting may differ from previous DHH results for several reasons. First these studies took place on different time scales (a 30 minute laboratory task versus hunting for an average of 8.4 hours) making comparability with the DHH study difficult. Thus while baseline cortisol and testosterone in the original DHH study was indicative of the current state of cortisol and testosterone in those individuals at the time of the task, the men in our hunting study were far removed from their baseline. Secondly, these men had already chosen to engage in the behavior of hunting, thus interactions between testosterone and cortisol that may have influenced their decision to hunt had occurred before our study began. Research in animal models often finds increased testosterone during competition despite relatively high levels of cortisol for animals that engage in male-male competition [3]. Thus while high levels of cortisol could shift behavior strategies toward avoiding competition, if an individual does engage in competition, then their muscle tissue would benefit from increased testosterone regardless of baseline cortisol. This benefit to muscle tissue would enhance ability to fight off another male, but could also enhance an individual's ability to flee.

Supplemental Figures



Supplemental Figure 1

The percent change in testosterone versus the percent change in cortisol at the time of the kill (r=0.88, p<0.001) and upon returning home (r=0.35, p=0.067).



Supplemental Figure 2

Heart rate (dark line) and accelerometery vector magnitude units (red bars) from three representative hunts where various animals were killed. Vector magnitude units indicate hunter movement as collected by tri-axial accelerometer. The hunter in Panel A, age 39, encountered a collared peccary (*Pecari tajacu*) at 9:52 AM, at which time he stalked and killed the animal at 9:54AM. The hunter in Panel B, age 28, encountered a capuchin (*Cebus apella*) at 16:35 PM, stalking and killing the animal at 16:59 PM. The third panel represents a hunter aged 48 years who encountered and immediately killed a collared peccary (*Pecari tajacu*) at 8:29 AM, encountered a coati (*Nasua nasua*) at 10:10 AM, chased and killed the animal at 10:30 AM, and encountered and immediately killed a lowland paca (*Cuniculus paca*) at 12:51PM.

Supplemental Work Cited

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5. Trumble B., Cummings D., Von Rueden C., O'Connor K., Smith E., Gurven M., Kaplan H. 2012 Physical competition increases testosterone among Amazonian forager-horticulturalists: a test of the 'challenge hypothesis'. *Proc R Soc B*, 1471-2954. (doi:10.1098/rspb.2012.0455).