# Basal testosterone, leadership and dominance: A field study and meta-analysis

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## ARTICLE INFO

## ABSTRACT

This article examines the role of basal testosterone as a potential biological marker of leadership and hierarchy in the workplace. First, we report the result of a study with a sample of male employees from different corporate organizations in the Netherlands ($n = 125$). Results showed that employees with higher basal testosterone levels reported a more authoritarian leadership style, but this relationship was absent among those who currently held a real management position (i.e., they had at least one subordinate). Furthermore, basal testosterone levels were not different between managers and non-managers, and testosterone was not associated with various indicators of status and hierarchy such as number of subordinates, income, and position in the organizational hierarchy. In our meta-analysis (second study), we showed that basal testosterone levels were not associated with leadership in men nor in women (9 studies, $n = 1103$). Taken together, our findings show that basal testosterone is not associated with having a leadership position in the corporate world or related to leadership styles in leaders. We suggest that basal testosterone could play a role in acquiring leadership positions through dominant and authoritarian behavior.

## 1. Introduction

Leadership styles are plastic, since leadership may be executed in different ways by different people depending upon contextual (Osborn et al., 2002) and personality factors (Hogan et al., 1994). The plasticity in leadership styles and behavior is evident in the scientific literature that has identified a myriad of different leadership styles in more than half a century of research on this topic (Yukl et al., 2002). An intriguing research question is whether these different leadership styles also have different or the same biological underpinnings. One of the potential biological mechanisms underlying leadership may be sustained levels of the hormone testosterone. The aims of this study are to investigate if basal testosterone levels are related to different leadership styles and if basal testosterone levels are associated with hierarchical positions in the workplace.

There is some reason to believe that testosterone may be related to leadership because high testosterone levels have frequently been related to high social status (Mazur and Booth, 1998), and leaders are considered of higher social status than non-leaders. Two mainstream theories on testosterone and behavior are consistent with this idea. According to the biosocial theory of status, gaining status -for instance by becoming a leader- increases testosterone levels whereas losing decreases it (Mazur and Booth, 1998), and according to the challenge hypothesis, testosterone levels increase in contexts relevant for reproduction such as when men strive for status (Archer, 2006). A different reason why leadership and testosterone may be related is that testosterone has frequently been associated with dominance displays (Archer, 2006; Mazur and Booth, 1998), and although leadership may be attained in different ways such as through prestige, it may also be gained through dominance. Indeed, various self-reported measurements of dominance have been shown to be related to high basal testosterone levels (Christiansen and Knussmann, 1987; Daitzman and Zuckerman, 1980; Gray et al., 1991; Sellers et al., 2007; Turan et al., 2014; van der Meij et al., 2008), although a few studies show no relationship for self-reports (Johnson et al., 2007; Slatcher et al., 2011). Furthermore, there is mixed evidence that high basal testosterone levels predicts implicit need for power (a non-declarative

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measurement of dominance, see Schultheiss, 2013). Finally, dominance as observed and rated by others is also related to high basal testosterone levels (Ehrenkranz et al., 1974; Slatcher et al., 2011). Interestingly, dominance has also been linked to testosterone in various non-human mammal species (Hirschenhauser and Oliveira, 2006). For example, high basal testosterone levels are related to higher dominance rank in Old World monkeys such as Rhesus Monkeys (Bernstein et al., 1983; Rose et al., 1975) and Crab-eating Macaques (Clarke et al., 1986; Czoty et al., 2009), but also in our close living relatives, Chimpanzees (Muehlenbein et al., 2004; Muller and Wrangham, 2004; Sobolewski et al., 2012). However, among our other closest relative, the more egalitarian bonobos, there is no association between male dominance rank and basal testosterone levels (Sannen et al., 2004).

Yet, there are also good reasons to doubt whether testosterone and leadership are related in humans. First, many different styles of leadership are not dominance-based (Bass and Bass, 2009), and it may be that these are unrelated to high testosterone levels. Indeed, anthropological studies show that hunter-gatherer societies are mostly egalitarian; leaders are elected democratically (Van Vugt et al., 2008), and domineering individuals may be excluded from the group or sanctioned (Boehm et al., 1993). Even today, 68.9% of all countries have fully or partly democratic regimes (The Economist Intelligence Unit, 2014). Furthermore, game theoretical models show that whereas dominance is a zero-sum game with winners and losers and a high degree of conflict between parties, leaders and followers are engaged in a mutualistic, collaborative- relationship where both parties can profit from coordination (Powers and Lehmann, 2014). There are also studies arguing that leadership in humans is often gained through prestige, which is acquired when people become experts in certain valued domains such as hunting, diplomacy or warfare (Henrich and Gil-White, 2001; King et al., 2009). Finally, psychological surveys show no systematic relationship between leadership and various personality measures of interpersonal dominance (Van Vugt, 2006).

Studies assessing both basal testosterone and leadership produce mixed findings. Some studies show positive relationships between high basal testosterone levels and leadership (Kerschbaum et al., 2006; Scaramella and Brown, 1978), whereas other studies show no relationship (Edwards and Casto, 2013; McIntyre et al., 2011; Zyphur et al., 2009), a negative relationship (Cashdan, 1995; Ronay and Carney, 2013), or only a positive relationship for leaders with low basal cortisol levels (Sherman et al., 2015). However, the majority of these studies have limitations. One important concern is that, with the exception of Sherman et al. (2015), all were conducted exclusively with student samples, and students typically have limited leadership and workplace experience. Thus, a question that remains unanswered is whether testosterone is related to leadership in people who occupy a formal position in the hierarchy of their organization (i.e., corporate managers). Another limitation of the previous studies is that none of them distinguished different leadership styles. Indeed, leadership is a broad concept that may differ across contexts substantially, and thus not surprisingly, many different leadership styles have been defined (Lewin et al., 1939; Redeker et al., 2014; Van Vugt et al., 2004). It may be that only some leadership styles are related to high basal testosterone levels and others are not. For instance, it could be that high basal testosterone levels are related only to dominant, authoritarian leadership styles, yet unrelated to more democratic, participative or laissez-faire leadership styles.

A potential moderator of the relationship between basal testosterone and leadership style may be the current hierarchical position of an individual. It could be that dominant behavior is more frequently displayed among individuals who have not yet a consolidated status position as dominance offers a way to climb the social hierarchy of a group. This prediction is in line with the mismatch effect (Josephs et al., 2006). According to this effect, individuals who have high basal testosterone levels but have a low status position experience arousal and distress, and try to actively reduce this state by increasing their dominance motivation. Indeed, laboratory studies have shown that when manipulating status by rigging a competition, those individuals high in testosterone but low in status, experience emotional arousal and experience a decrease in performance on complex cognitive tasks (Josephs et al., 2006). Furthermore, there is evidence that collective efficacy is lower in student workgroups in which basal testosterone levels of individuals do not match their status position (Zyphur et al., 2009). Perhaps these miss-matched individuals engage more in status striving rather than focussing on their work.

On both theoretical and empirical grounds, as reviewed above, we expected that higher testosterone levels were related to a dominant leadership style but unrelated to other, more democratic and participative leadership styles. We also explored if the testosterone-leadership style relationship was different for people in a consolidated versus an unconsolidated leadership position (managers vs. non-managers). Furthermore, we investigated whether managers had higher basal testosterone levels than non-managers and explored the relationship between basal testosterone and several indicators of leadership such as one's position in the organizational hierarchy, income, and the number of subordinates a person manages. To test our hypotheses, we performed a field study and a meta-analysis. In the field study, we measured basal testosterone levels and self-report leadership style in a unique sample of male (and a small group of female) employees from various companies in the Netherlands, both managers and regular employees. In the meta-analysis, we investigated if leaders have different basal testosterone levels than non-leaders when also including the effect sizes of previous studies on basal testosterone and leadership.

## 2. Methods field study

### 2.1. Participants

Our final sample size consisted of 125 corporate men. Data was collected on more participants but they were excluded due to the following reasons: two participants were excluded since they had severe health problems (e.g., depression, heart problems), two participants were excluded because they used medication that influenced their emotional appraisal and/or hormonal levels (e.g., benzodiazapines, testosterone supplements), three participants did not complete the entire leadership questionnaire, one participant had extreme low testosterone levels of 23 pmol/L, and nine participants did not provide enough saliva. We report the results on women separately in the Supporting information (see Table S4), since there were too few women in the sample to be included in the main analyses. Participants did not receive money for participating but if desired they received a report on their leadership style and basal testosterone level.

Participants were recruited through the network of MANDEV (a company providing management training) or through the executive program of Nyenrode Business Universiteit. Participants were on average 36 yrs. old (Median = 34, $SD = 9$, min = 22, max = 67) and 91.2% of the participants had a university degree. Participants worked on average 46 h per week ($SD = 9$, min = 10, max = 75) and on average worked 8 h more than they were paid for ($SD = 8$, min = −10, max = 48). The median number of people working at their organization was 170 ($M = 8641$, $SD = 27,912$, min = 1, max = 250,000) and the median of worked years with their current employer was 4 years ($M = 6$, $SD = 6$, min = 0, max = 34). On average they rated their place in the hierarchy of their organization on a scale from 1 (highest) to 7

(lowest) a 2.688 (SD = 1.25, min = 1 max = 7). Median annual income before tax was €60,000 (M = €72,473, SD = €45,671, min = €2,700, max = €275,000). Participants worked in the following economic sectors: 18.4% financial services, 16.8% retail and wholesale, 15.2% industry, 8.8% construction, 8.8% consultancy, 8% ICT and facility management, 6.4% agriculture, 4.0% education, 3.2% health care, 3.2% transportation, 7.2% rest category.

Eighty-two participants reported to be a manager, having one or more direct subordinates working for them, and 43 participants reported not to be a manager −they were not supervising any subordinates-. Managers had a higher annual gross income ($t_{119}$ = 3.294, $p$ = 0.001), were older ($t_{122.49}$ = 6.090, $p \leq$ 0.001), and reported a higher place in the hierarchy of their organization ($t_{123}$ = −6.031, $p \leq$ 0.001) than non-managers. Managers supervised a median of 8.50 subordinates (M = 18.55, SD = 29.88, min = 1, max = 230).

### 2.2. Procedure

The first data collection period spanned several months. To collect saliva samples and to administer the questionnaires the experimenters traveled to the location of the participants. After arrival the general purpose of the study was explained and participants signed an informed consent form. Next, participants filled in the paper short version of the Leadership Circumplex (Redeker et al., 2014). Participants also completed a socio-demographic questionnaire, a general health questionnaire, and finally provided a saliva sample to measure their basal testosterone levels. The protocol of the second data collection period was similar to the first except that participants filled in an online version of the leadership questionnaire at a time of their choosing after saliva sampling. On average participants did not score differently on this online questionnaire (all $p \geq$ 0.355). Across both data collection periods saliva sampling was mostly done in the morning to avoid effects of the circadian rhythm (Median = 10:30, M = 11:26, SD = 01:53, 14.4% of participants donated saliva after 12:00, saliva collection was between 09:49 and 16:53). When all the measurements were taken the participants were thanked and debriefed. Ethical approval was provided by the Nyenrode Business Universiteit.

### 2.3. Leadership questionnaire

To assess a person's self-reported leadership style participants filled in a short version of the Leadership Circumplex in Dutch (Redeker et al., 2014). Participants were asked to provide self-ratings on 116 leadership descriptive items on a 5-point Likert scale ranging from 1 (never) to 5 (always). Reliabilities were low for some of the original leadership styles (Cronbach's α: 0.53–0.83), and therefore we performed a factor analysis to investigate whether items would saturate in more reliable constructs. This analysis showed three leadership styles: authoritarian leadership, item example: "Is bossy" (α = 0.81, 10 items); laissez-faire leadership, item example: "Hesitates to express own preferences" (α = 0.76, 12 items); democratic leadership, item example: "Encourages employees to perform better in a positive way" (α = 0.82, 11 items). These three leadership styles are similar to the three leadership styles already defined by Lewin et al. (1939). Non-managers also filled in the leadership questionnaire, since they did report having experience exercising leadership as they sometimes led project teams at work. See Supporting Information for more details on the leadership questionnaire, a correlation matrix of the studied variables, and descriptive statistics of the manager and non-manager group.

### 2.4. Hormonal analyses

Testosterone levels in saliva were determined with the highly sensitive and accurate isotope dilution-liquid chromatography–tandem mass spectrometry method (ID-LC–MS/MS, see (Bui et al., 2013)). This method features an inter-assay variation of 5% at 200 and 2000 pmol/L and the intra-assay variation at 10, 140, and 900 pmol/L are 11%, 4%, and 2%, respectively. The lower limit of quantification (LOQ) was 8 pmol/L. Participants deposited 2 ml of saliva in small plastic vials which took approximately 5 min to fill. The samples were then frozen at −20 and sent frozen to be assayed for testosterone. The saliva samples were analyzed in duplicate by the Endocrine Laboratory of the department op Clinical Chemistry of the VU University Medical Center (Amsterdam, The Netherlands). Outliers were assessed using the raw testosterone values according to two criteria: testosterone levels that differed more than 3 SD from the mean (two outliers were identified) or were more than three interquartile ranges below the first quartile or above the third quartile (no outliers were identified). Removal of the two outliers did not change the statistical conclusions.

### 2.5. Statistical analysis

We first investigated whether leadership style was related to basal testosterone levels and whether management position moderated this relationship. To do so, we performed a moderator regression analysis according to Aiken and West (Aiken and West, 1991). In Step 1, we included saliva sampling time, age, and data collection period as covariates.[1] In Step 2, we added the standardized basal testosterone levels and management position (1 = ≥1 subordinates, 0 = no subordinates), and in Step 3, we added the interaction between standardized basal testosterone levels and management position. We used partial correlations to investigate which items of the leadership questionnaire correlated with basal testosterone levels (controlling for saliva sampling time, age, and data collection period).[1] Finally, we then investigated whether managers vs non-managers had different leadership styles (democratic, authoritarian, laissez-faire) by performing an ANCOVA for each leadership style while controlling for age and data collection period.

We then investigated whether basal testosterone levels were different for managers (≥1 direct subordinates) and non-managers (no direct subordinates) with an ANCOVA. As dependent variable we included basal testosterone levels and as independent variable we included management position (manager or non-manager), and we included the following covariates: saliva sampling time, age, and data collection period (first or second).[1] Also, we investigated in managers and across all participants whether basal testosterone levels were related to the following indicators of leadership: annual gross income (four participants did not answer this question), position in the company's hierarchy, and in managers, the number of subordinates with partial correlations (controlling for saliva sampling time, age, and data collection period). We also correlated age with basal testosterone levels while controlling for saliva sampling time and data collection period.

In all analyses the following variables were log or square root transformed since these variables were not normally distributed: testosterone (log), gross annual income (log), and age (log), the number of subordinates (sqrt since it contained zeros). For the statistical analysis SPSS 22.0 was used and $p$ values ≤ 0.05 (two tailed) were considered statistically significant.

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[1] Excluding these covariates did not change the statistical conclusions of these analyses.
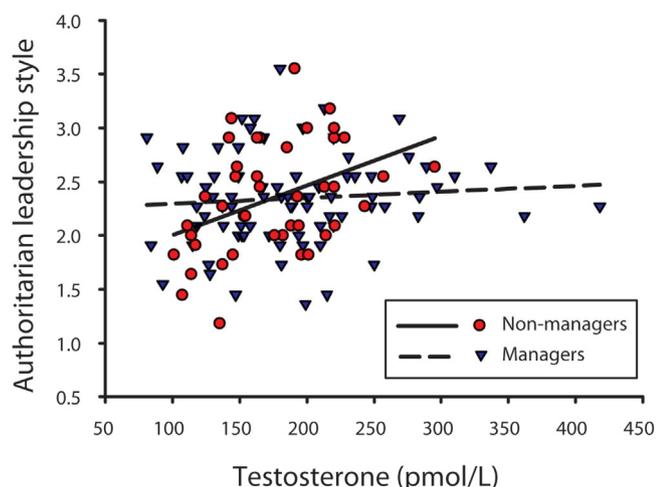
**Fig. 1.** Scatter plot showing the moderation of management position on the relationship between basal testosterone levels and self-reported authoritarian leadership style.

## 3. Results field study

### 3.1. Basal testosterone and leadership styles

Higher basal testosterone levels were related to more authoritarian leadership style, although this relationship was marginally significant (in Step 2: $\beta = 0.175$, $p = 0.057$). However, management position moderated the relationship between basal testosterone and authoritarian leadership style (Step 3: $\Delta R^2$ *change* = 0.051, $\Delta F_{1118} = 6.695$, $p = 0.011$), see Fig. 1. Higher basal testosterone levels were related to a more authoritarian leadership style only in non-managers ($\beta = 0.262$, $p = 0.002$), and not for managers ($\beta = 0.022$, $p = 0.628$).

Higher basal testosterone levels were not related to a democratic leadership style (in Step 2: $\beta = -0.040$, $p = 0.662$) and management position did not moderate this relationship (Step 3: $\Delta R^2$ *change* = 0.006, $\Delta F_{1118} = 0.692$, $p = 0.407$). Furthermore, higher basal testosterone levels were not related to laissez-faire leadership style (in Step 2: $\beta = -0.128$, $p = 0.170$) and management position did not moderate this relationship (Step 3: $\Delta R^2$ *change* = 0.001, $\Delta F_{1118} = 0.114$, $p = 0.736$).

### 3.2. Basal testosterone: management position and indicators of leadership

The results showed that basal testosterone levels were not significantly different between managers ($M = 187.98$ pmol/L, $SD = 64.52$, $n = 82$) and non-managers ($M = 175.65$ pmol/L, $SD = 44.69$, $n = 43$; $F_{1120} = 2.291$, $p = 0.133$, $\eta^2_p = 0.019$). In the subgroup of managers, basal testosterone levels were unrelated to annual gross income ($pr_{74} < 0.001$, $p > 0.999$), place in the hierarchy of their organization ($pr_{77} = -0.067$, $p = 0.557$), age ($pr_{78} = -0.170$, $p = 0.131$), and the number of subordinates supervised ($pr_{77} = 0.026$, $p = 0.817$). Across all participants, basal testosterone levels were also unrelated to annual gross income ($pr_{116} = 0.053$, $p = 0.569$), place in the hierarchy of their organization ($pr_{120} = -0.108$, $p = 0.238$), age ($pr_{121} = -0.111$, $p = 0.220$), and the number of subordinates supervised ($pr_{120} = 0.109$, $p = 0.234$).

Finally, participants' leadership style (authoritarian, democratic and laissez-faire) was not different between managers and non-managers (authoritarian: $F_{1,121} = 0.330$, $p = 0.567$, $\eta^2_p = 0.003$; Democratic: $F_{1,121} = 0.098$, $p = 0.755$. $\eta^2_p = 0.001$; Laissez-faire: $F_{1,121} = 0.489$, $p = 0.486$, $\eta^2_p = 0.004$).

## 4. Methods meta-analysis

### 4.1. Selection of studies meta-analysis

We performed a meta-analysis to investigate whether basal testosterone levels and leadership were related when combining the effect sizes from the field study with other studies on this topic. To do so, we searched for studies in databases Google Scholar, Pubmed, and Web of Science with the following keywords: "testosterone"; "leadership". We included studies that assessed adult basal testosterone levels and those studies that measured leadership in naturally occurring groups; leaders were either assigned by peers or were in a formal leadership position. Studies were excluded according to the following criteria: (i) lab studies assessing testosterone levels while manipulating leadership or dominance rank (participants in these experiments did not attain leadership by their own choice or effort); (ii) studies on dominance or competition (dominance is a different construct than leadership); (iii) studies sampling boys (leadership in boys can partly be determined by physical dominance; such as rough play with other children, see Pellegrini, 1995). To obtain unpublished results we emailed the authors of all the studies we included in our review and asked them if they knew of or had any unpublished work on testosterone levels and dominance or leadership measurements. This approach resulted in the inclusion of 9 studies ($n = 1103$). To account for possible sex differences we coded for the sex of participants within each study. Four studies included both male and female participants and for these studies we entered the effect sizes for men and women as separate studies. This led to the inclusion of seven effect sizes for male leadership ($n = 622$); and six effect sizes for female leadership ($n = 481$). See Table 1 for the included studies.

### 4.2. Analyses meta-analysis

As effect size we reported Pearson correlation ($r$), since most studies correlated testosterone levels with leadership measurements. Positive $r$ values indicate a positive relationship between basal testosterone levels and leadership measurements. Unless otherwise specified, we used raw testosterone values, i.e., not controlled for sampling time, not log transformed and including outliers. For most studies we could obtain Pearson correlation coefficient, however, for one study we used a $p$-value and sample size.

To investigate whether leadership was related to testosterone levels we assumed a random-effects model (i.e., that the true effect size varied per study) and we assessed if there was heterogeneity in effect sizes ($\tau$, $\tau^2$, $I^2$, $Q$). Normal distribution of effect sizes could not be assessed reliably due to the small sample size. Outliers were assessed by inspecting the forest plot. Furthermore, we investigated if there was a publication bias with Egger's regression intercept and Duval and Tweedie's trim and fill (Duval and Tweedie, 2000). In the subgroup analysis investigating sex differences we used a mixed-effects model since we assumed the studies within the two subgroups did not share a common effect size (random effect) and assumed that any comparison between men and women would include these two subgroups (fixed effect). Furthermore, in the subgroup analysis, we did not pool the variance of the true effect size ($\tau^2$), since it could be that study-to-study dispersion may be different for men and women.

Finally, following the same approach as above, we investigated whether the number of subordinates was related to basal testosterone levels in managers/executives. To this end, we included the effect size of our field study ($pr_{77} = 0.026$, $n = 82$) and the effect size of Sherman et al. (2015), $r_{78} = 0.22$, $n = 78$. Publication bias, outliers, and heterogeneity in effect sizes were not assessed due to the small sample in this last analysis. ($n = 2$). All meta-analyses were com-

**Table 1**
Studies included in the meta-analysis assessing testosterone levels and leadership.

| Study | $n$ | $r$ | Sex | Population | Assessor | Leadership measurement | Testosterone | Sampling time |
|---|---|---|---|---|---|---|---|---|
| Cashdan (1995) | 32 | −0.11[a] | Women | Students | 10 students living together in center | Leadership ranking of other group members on yardstick | Serum | 1 h after rising |
| Edwards and Casto (2013) | 74 | 0.00 | Women | Students | Players of sports team | Player Rating Scale (fifteen items, 5-point scale)[b] | Saliva | 12:00–20:00 |
| Kerschbaum et al. (2006) | 23 | 0.42 | Men | Students | Peers[c] | Name most effective leader | Saliva | Unknown |
| | 19 | −0.46 | Women | | | | | |
| McIntyre et al. (2011) | 71 | −0.02[d,e] | Men | Students | 7–9 students living together in suite of several rooms | Leadership ranking of other group members on ruler | Saliva | 06:00–01:10 |
| Ronay and Carney (2013) | 52 | −0.25[f] | Men | Students | At least 8 peers | Nine questions on interpersonal leadership skills and abilities (7-point scale)[g] | Saliva | 12:30–16:30 |
| | 22 | −0.05 | Women | Students | | | | |
| Scaramella and Brown (1978) | 14 | 0.20 | Men | Students | 2 coaches | Rating on the item "leadership" (7-point scale) | Serum | 15:30–16:00 |
| Sherman et al. (2015) | 78 | 0.22 | Men | Executives | Self-report | No. of subordinates | Saliva | 15:30–16:00 |
| van der Meij et al. (2016)[h] | 125 | 0.10 | Men | Business men | Self-report | Leader (≥1 subordinate) vs. non-leader (0 subordinates) | Saliva | 09:49–16:53 |
| | 14 | −0.29 | Women | | | | | |
| Zyphur et al. (2009) | 259 | 0.006[f] | Men | Students | 4–7 group members | Five questions on leadership (7-point scale)[i] | Saliva | Afternoon |
| | 320 | 0.006[f] | Women | | | | | |

[a] This is for free testosterone, for total testosterone $r$ was 0.23.
[b] Item examples are: "she finds ways to elevate the level of play of her teammates" and "Please provide an overall rating of the individual's abilities as a team "leader."".
[c] Number of peers unknown. Age range was 17–19 years old, assessed correlation with p value of 0.49 ($p$ from article < 0.05).
[d] Log transformed testosterone levels.
[e] This is for late day testosterone level, for time adjusted morning testosterone levels it was $r = -0.002$, $p = 0.0987$.
[f] Personal communication.
[g] Item examples are: "fails to direct meetings in his/her favor (reverse coded)", "makes effective use of other people's advice in making decisions".
[h] See results field study in this article.
[i] Item examples are: "This individual influences group goals and decisions", and " This individual leads conversation in the group".

puted by following the procedure of Borenstein et al. (2009) with the software program Comprehensive Meta Analyses version 2.

## 5. Results meta-analysis

The meta-analysis on studies assessing leadership showed that basal testosterone levels and leadership were unrelated ($r_{13} = 0.007$, 95% CI [−0.077, 0.091]), see Fig. 2. Effect size variance could not be explained by between study differences ($\tau = 0.081$, $\tau^2 = 0.007$, $I^2 = 32.791$, $Q_{12} = 17.855$, $p = 0.120$). Inspection of the forest plot did not reveal any outliers. Egger's regression intercept showed no evidence of publication bias (Intercept = −0.347, $t_{11} = 0.489$, 95% CI [−1.909, 1.215]). However, Duval and Tweedie's trim and fill approach revealed that two studies could be filled above the estimated effect size. Addition of these studies resulted in a slightly bigger overall effect size ($r = 0.030$, 95% CI [−0.061, 0.121]). Additionally, it appeared that the relationship between leadership and basal testosterone was not different for men and women ($Q_1 = 1.511$, $p = 0.219$). Basal testosterone levels were neither related to male leadership ($r_7 = 0.061$, 95% CI [−0.062, 0.182]) nor to female leadership ($r_6 = -0.035$, 95% CI [−0.125, 0.056]). Finally, results showed that number of subordinates were unrelated to basal testosterone levels in male managers/executives when combining the findings from Sherman et al. (2015) and our field study ($r_2 = 0.123$, 95% CI [−0.070, 0.307]).

## 6. Discussion

Are higher basal testosterone levels related to a more dominance-based leadership style? The field study showed that high basal testosterone levels were related to a more authoritarian leadership style yet only in non-managers. A tentative explanation is that high basal testosterone levels may foster authoritarian leadership only if this could result in obtaining a high status position.

This explanation is in line with the mismatch hypothesis, which predicts that individuals low in status (e.g., non-managers) but high in basal testosterone levels have a greater dominance motivation, as these individuals try to climb up the social hierarchy (Josephs et al., 2006). Whether or not this dominance behaviour actually leads to more status is unclear. There is research showing that dominant individuals exercise more influence in a group, because they are seen as more competent (Anderson and Kilduff, 2009), and competitive people are more likely to emerge as leaders (Marinova et al., 2013). However, there seems to be a trade-off regarding leadership, as high basal testosterone levels are also associated with less emphatic accuracy (Ronay and Carney, 2013) and less prestige (Johnson et al., 2007). In the long-run high testosterone levels could undermine effective leadership, as it could make it more difficult for managers to tune in with the needs of their subordinates, a prerequisite for leadership (Van Vugt et al., 2008). In line with this, once individuals consolidate their status position and ascend to management positions, they may find that certain leadership styles reduce their ability to lead, since dominant behavior can be counterproductive in influencing subordinates. Indeed, business studies reveal that leaders who operate in a more autocratic manner undermine team communication and cooperation between team members (Tost et al., 2012). Thus, in managers, high basal testosterone levels would not foster authoritarian leadership, since their team's performance would decrease together with the manager's status.

So do real-world leaders have different basal testosterone levels than non-leaders? Findings from both our field study and meta-analysis suggest this is not the case. The field study showed that corporate managers did not differ significantly from non-managers in basal testosterone levels. Granted there was a small, non-significant trend showing that leaders had elevated basal testosterone levels. This effect may have been statistically significant if our study had included a substantially bigger sample size

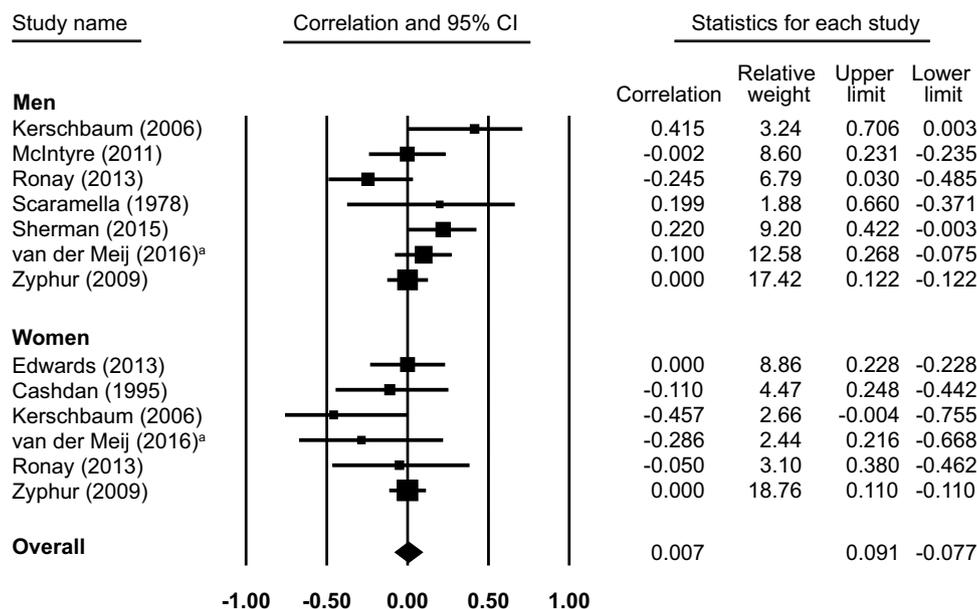## Relationship between basal testosterone and leadership

| Study name | Correlation and 95% CI | Statistics for each study | | | |
|---|---|---|---|---|---|
| | | Correlation | Relative weight | Upper limit | Lower limit |
| **Men** | | | | | |
| Kerschbaum (2006) | | 0.415 | 3.24 | 0.706 | 0.003 |
| McIntyre (2011) | | -0.002 | 8.60 | 0.231 | -0.235 |
| Ronay (2013) | | -0.245 | 6.79 | 0.030 | -0.485 |
| Scaramella (1978) | | 0.199 | 1.88 | 0.660 | -0.371 |
| Sherman (2015) | | 0.220 | 9.20 | 0.422 | -0.003 |
| van der Meij (2016)[a] | | 0.100 | 12.58 | 0.268 | -0.075 |
| Zyphur (2009) | | 0.000 | 17.42 | 0.122 | -0.122 |
| **Women** | | | | | |
| Edwards (2013) | | 0.000 | 8.86 | 0.228 | -0.228 |
| Cashdan (1995) | | -0.110 | 4.47 | 0.248 | -0.442 |
| Kerschbaum (2006) | | -0.457 | 2.66 | -0.004 | -0.755 |
| van der Meij (2016)[a] | | -0.286 | 2.44 | 0.216 | -0.668 |
| Ronay (2013) | | -0.050 | 3.10 | 0.380 | -0.462 |
| Zyphur (2009) | | 0.000 | 18.76 | 0.110 | -0.110 |
| **Overall** | | 0.007 | | 0.091 | -0.077 |

-1.00  -0.50  0.00  0.50  1.00

**Fig. 2.** Forest plot of the studies measuring leadership and basal testosterone levels separated by sex. Overall = overall random effect. [a]Results field study in this article.

($n = 408$) while assuming the same very small effect size would hold ($\eta^2_p = 0.019$). Yet we very much doubt if such a small effect size is meaningful in any way. Furthermore, men's basal testosterone level did not vary with their position in the organizational hierarchy, nor with other indicators of leadership such as leadership style, number of subordinates, or income. One interpretation is that dominant behavior is not being tolerated in modern workplace environments (Judge et al., 2009). Leaders may be more successful by displaying social tolerance. In line with this, research shows that individual and team performance increases by empowering employees through delegating responsibility and authority (Chen et al., 2007).

The meta-analytic finding was in line with the results from the field-study in that high basal testosterone levels were unrelated to leadership in both men and women when combining the available studies in the literature. These non-significant findings from the field study and meta-analysis are consistent with the idea that leadership and dominance may not share the same biological mechanism. Indeed, high testosterone levels have been related frequently to dominance in prior research (Archer, 2006; Mazur and Booth, 1998). However, in real-world organizations leadership is probably more often based on prestige and voluntary deference rather than on coercion, intimidation and competition (Price and Van Vugt, 2014). These null findings are also consistent with animal behavior studies showing that dominance rank does not necessarily predict which individual coordinates group movement or maintains group cohesion (King et al., 2009). However, caution has to be taken in interpreting the meta-analytic findings. There was some considerable heterogeneity in the measurement of leadership; some studies included samples of people in formal leadership positions (managers) while other studies involved informal leadership primarily in student peer groups (see Table 1 for the exact definitions). This heterogeneity in measures can be considered a weakness in this research, since the effect of basal testosterone on leadership could differ substantially from sample to sample. Indeed, our own field study shows that this relationship depends on someone's current status position. Our results thus suggest that more research needs to be done outside the lab with people in for-

mal leadership positions in business, politics and the army so that future meta-analyses provide a more complete picture.

Our field study had some limitations. First, our results are limited to the corporate world and it is possible that in other organizational contexts, such as the military, leadership is related to high basal testosterone levels. Research shows that uncertainty increases support for and trust in authoritarian leadership (Rast et al., 2013), suggesting that authoritarian leaders with high basal testosterone levels are better at dealing with uncertain situations. Indeed, in war time scenarios voters prefer leaders with more masculine-looking faces (Spisak et al., 2012), a proxy of high basal testosterone levels (Penton-Voak and Chen, 2004), but the opposite is found during peacetime. A second limitation is that in the field study leadership styles were assessed through self-reports, and self–other agreement between leaders and followers can be relatively low (De Vries, 2012). Thus, it would be better to rely on the reports of subordinates in a subsequent study. Third, our field study was unable to assess the causal direction in the relationship between testosterone and authoritarian leadership? Fourth, it remains to be seen if basal testosterone levels are also unrelated to an authoritarian leadership style in female managers. Our sample did not include enough female managers to properly test this relationship (see supporting information for preliminary findings). Fifth, our field study used a sample of workers from the Netherlands, a relative egalitarian country (Hofstede, 1994). In our study, self-reported authoritarian leadership style was unrelated to income, hierarchy, and number of subordinates (see Table S2 in Supporting information). Conversely, Dutch managers who had more subordinates were more likely to adopt a more democratic leadership style. These results suggest that in the Netherlands dominant leadership is generally regarded as ineffective (see also Koopman et al., 1999), and it is possible that we would have obtained different results in workplaces in more hierarchical, masculine countries such as the United States or Japan (Hofstede, 1994). This remains to be seen.

Finally, we would like to emphasize that we focused only on basal testosterone as a possible hormonal marker of leadership and hierarchy. Yet there are other hormones to consider when study-

ing leadership and management, such as cortisol. For example, high activity between the hypothalamus-gonadal-axis (end product: testosterone) and low activity from the hypothalamus-pituitary-axis (end product: cortisol) may result in more status-driven behavior (Mehta and Josephs, 2010; Terburg et al., 2009). A recent study showed that high basal testosterone levels were related to having more subordinates yet only in executives low in basal cortisol level (Sherman et al., 2015). It could thus be that cortisol moderates the relationship between testosterone and leadership style in managers. Future research could assess whether corporate managers who display a more dominant leadership style are distinguished by a pattern of high basal testosterone levels with low basal cortisol levels. Although looking at interactions with other hormones is in itself valuable, we think it is of critical importance to establish whether there is a main effect of basal testosterone on leadership in the corporate world.

As a final note, we should mention that our results are strikingly similar to classic research involving olive baboons. In this species, a subset of subordinate males with high testosterone levels frequently initiate fights with other baboons in an attempt to gain status (Virgin and Sapolsky, 1997). Similarly, in our study the low status men -the non-managers- with high testosterone levels may have adopted a similar strategy, displaying authoritarian behaviors to attain a position of leadership. Furthermore, in olive baboons, high status males have no different testosterone levels than subordinate males when the hierarchy is stable (Sapolsky, 1983). This observation is similar to our finding showing that managers had no different testosterone levels than non-managers. However, during hierarchical instability, aggressive high status baboons have higher testosterone levels than subordinate baboons (Sapolsky, 1983). Unfortunately, we did not assess the stability of people's leadership positions in our study, but it would be interesting to see whether managers will resort to more coercive tactics accompanied by elevated testosterone levels when their status position is threatened.

Taken together, our study showed a relationship between basal testosterone levels and authoritarian leadership style, but only among workers currently not in a formal hierarchical position. Among managers, there was no significant relationship between testosterone and leadership styles. This suggests that the relationship between testosterone and leadership styles depends upon the context; those men not in a leadership position may be trying achieve a formal leadership position through displaying dominant behavior. Our results may point to an important conceptual and empirical distinction between dominance and leadership. One of the potential biological mechanisms underlying dominance - sustained levels of basal testosterone- does not distinguish leaders from non-leaders in the workplace. It remains to be seen whether these findings can be generalized across other domains such as sports, the army, and politics, or other cultures and countries.

## Conflicts of interest

None.

## Contributors

LvdM, MvM and JS have contributed to the conception and design of the study, and have given input on the interpretation of the data. LvdM and JS have done the data acquisition. LvdM has drafted the article and performed the statistical analyses. MvV, JS, and LvdM have revised the article critically for important intellectual content. All authors have approved the final article.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.psyneuen.2016.06.005.

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