ANTHROPOLOGIA INTEGRA
4/2013/2
ČASOPIS PRO OBECNOU ANTROPOLOGII A PŘÍBUZNÉ OBORY
JOURNAL FOR GENERAL ANTHROPOLOGY AND RELATED DISCIPLINES

The Correlations between Handgrip Strength and Several Psychosomatic Features in Homo sapiens – a review

Daniela Cunha[1], Filipe Monteiro[1], Yasin Hamarat[2], Martin Čuta[3]

[1] University of Coimbra, Coimbra, Portugal
[2] Bülent Ecevit University, Zonguldak, Turkey
[3] Department of Anthropology, Faculty of Science, Masaryk University, Vinařská 5, 603 00 Brno

Received 10th of September 2013; accepted 22th of November 2013

VZTAH MEZI SÍLOU STISKU RUKY A NĚKTERÝMI PSYCHOSOMATICKÝMI RYSY U HOMO SAPIENS PŘEHLEDOVÝ ČLÁNEK

ABSTRAKT Síla stisku ruky je velmi dobrým ukazatelem zdraví, výkonnosti kosterního svalstva a celkově je dobrým indikátorem zdravotního stavu a vitality. Testosteron je hormon, který je primárně zodpovědný za rozvoj sekundárních pohlavních znaků a zároveň má silný vztah k tělesné síle a zevním ukazatelům rozvoje skeletální svaloviny. Byla publikována řada prací, které poukazují na úzký vztah mezi testosteronem a agresí. Nebyl však doposud vysvětlen kauzální vztah mezi hladinou testosteronu a výsledným agresivním chováním, tedy konkrétní působení metabolitů testosteronu ve specifických oblastech mozku. Na základě publikovaných experimentálních prací jsou diskutována některá možná/částečná vysvětlení působení testosteronu na vznik agresivního chování. Dále je diskutován vztah mezi silou stisku ruky a lidským sexuálním chováním – tedy sexuální dimorfismus v síle stisku, ženská percepce (v rozdílných fázích menstruačního cykly) stisku ruky u mužů a volba partnera ve vztahu k jeho fitness (jak je hodnocena dle síly stisku ruky, jež je dobrým ukazatelem hladiny testosteronu).

KLÍČOVÁ SLOVA testosteron; síla stisku ruky; agrese; sexuální chování

ABSTRACT Handgrip strength (HGS) is a very good marker of physical health, good muscle performance and an overall indicator of health status and vitality. Testosterone, as a hormone primarily responsible for secondary sexual traits development, is also strongly correlated to body strength and somatic features which represent it. It has been widely reported that testosterone correlates with aggression. However, the pathway of testosterone metabolites in specific brain regions, or cause and effect formula of testosterone level and aggression has not been satisfactorily explained. Several possible and/or partial explanations based on published experiments are discussed. Furthermore, the relation between HGS and human sexual behavior is discussed – the sexual dimorphism in HGS, the perception of male HGS by females at different stages of the menstrual cycle and the selection of a partner with respect to his fitness (as estimated by HGS which is a good indicator of testosterone level).

KEY WORDS testosterone; handgrip strength; aggression; sexual behavior

INTRODUCTION

When looking at the evolutionary history of hominids, and primates in general, we see that many complex adaptations emerged for life in the trees, which required good visual acuity, depth perception and color distinction but also strong and sophisticated brachiation movements and strength (Gallup, White, Gallup 2007; Shoup, Gallup 2008). In modern humans the handgrip strength (HGS) is part of that legacy, and it's a very good marker of physical health, good muscle performance and an overall indicator of health status and vitality (Gallup, White, Gallup 2007).

HGS is a highly hereditable characteristic and is sexually dimorphic. This is due to males having more muscle mass and it's a trait driven by androgen hormones, with testosterone having a key role (Gallup, White, Gallup 2007). Male HGS "*is an indicator of selection during evolutionary history for overall physical strength among males*" (Gallup, White, Gallup 2007, p.: 426): it predicts body morphology, aggressive and sexual behavior (Gallup, White, Gallup 2007). Besides that, high HGS is correlated to predictions of better health status, longevity, faster recovery from injuries and reduced morbidity, protein, muscle and body fat losses (Gallup, White, Gallup 2007; Henderson, Anglin 2003).

The fact that HGS has a gender asymmetry means it is a fitness indicator. According to the authors Gallup, White and Gallup (2007), upon coming from the trees, "*a primitive division of labor emerged and put a premium on the maintenance and further elaboration on grip strength in men*" (p.: 428). Higher HGS in males is closely linked to a more aggressive behavior (evolutionarily linked to hierarchy formation, social dominance and reproductive success) and more pronounced promiscuity (they have more sexual partners and start having sexual intercourse earlier) (Gallup, White, Gallup 2007; Shoup, Gallup 2008). Higher HGS also correlates with a more masculine shape (broader shoulders, narrower waist) and a more masculine and handsome face (symmetric with broader faces and more prominent cheekbones). All these traits are influenced by the environment but they're also highly heritable, desired by females and generally indicate signals of good genes operating under sexual selection (inter-male competition) (Gallup, White, Gallup 2007; Shoup, Gallup 2008; Henderson, Anglin 2003).

All these traits' variations in the male population stem from one leading factor – the testosterone levels and its complex interaction in developing secondary sexual traits; testosterone is the main explanation behind why all these variables correlate with aggressive behavior, promiscuity and a more masculine body-type and face. Testosterone and its relation with aggression (with consequent physical and/or social dominance) influence the correlations of male facial width-height ratio with cooperation and trust/punishment (Shoup, Gallup 2008; Stirrat, Perrett 2010; Haselhuhn, Wong 2012; Stirrat, Stulp, Pollet 2012): men with greater facial width (broader face) are more likely to exploit, cheat and lie to others and trust less than the counterparts with narrower faces (Haselhuhn, Wong 2012). Also, men with broader faces are less likely to die from violent contact showing that they are more willing to fight and therefore more likely to survive aggressive situations (Stirrat, Stulp, Pollet 2012). Being all sexually dimorphic, heritable traits tied together with aggression and dominance/competition between males for status and resources (including sexual partners) led to the emergence of cognitive mechanisms to access information from visual cues to better evaluate competitor's formidability (stamina, strength, fighting ability and resource-holding potential) and overall good fitness so that they could avoid costly fights/disputes against them (Sell et al. 2009). Visual cues from the face and upper body of males allow the assessment of aggression, exploitation, deception, physical violence and overall unethical behavior (Shoup, Gallup 2008; Stirrat, Stulp, Pollet 2012; Sell et al. 2009) by the conspecifics and all these traits are correlated to masculinity. All these traits emerged through evolutionary time linked together as a "*package of features that collectively and individually signal fitness*" (Shoup, Gallup 2008, p.: 476). Handgrip strength is highly correlated to all these variables and, in men it's a very good proxy for testosterone levels, more accurate than 2D4D and facial width-height ratios (Gallup, White, Gallup 2007; Shoup, Gallup 2008). This "package" of features in males stems from one complex interaction present in many animal species: testosterone and aggression.

THE RELATIONSHIP BETWEEN TESTOSTERONE AND AGGRESSION

Testosterone is an androgen that has been implicated in the development and maintenance of masculine characteristics in a variety of species (Mazur, Booth 1998). It has been documented that females of most species are less aggressive and have far lower testosterone levels than do males; this is taken as evidence of a link between testosterone and aggression (Archer 1991). How exactly testosterone affects aggression and dominance behavior is unknown (Mazur 1983), but multiple pathways have been proposed (Simon et al. 1996).

It's a common myth that testosterone causes aggression but is there biological reason to back up this assertion? Some say there is, while emphatically rattling off statistics and experimental evidence, while still others are armed with ambiguous or even refuting information with which to contest this argument. The bottom line is that we do not know for sure whether or not testosterone causes aggression (how problematic the idea of cause and effect can be in biology!) and so at this point we must turn away from the enticing idea that there exists a clear and definitive answer to this question. We must instead turn our attention to the evaluation of available information, in order to better understand the role of testosterone in guiding behavior.

According to a theory from evolutionary biology, aggression serves an important function in terms of both individual survival as well as procreation potential. In terms of this evolutionary biological theory, what it comes down to is this: competition arises when resources are limited and therefore animals/species must actively compete in order to increase their own fitness. It does not take a biologist to then infer that aggression is advantageous at both the individual and genetic levels.

Hormones are inextricably linked to behavior as seen by the impact that its presence or absence has on an organism. In terms of aggression, there exists intriguing evidence that there is a definite connection between the hormonal effects of testosterone and the outward expression of aggressive behavior. For example, castration leads to a marked decrease in aggression as shown by castration experimentation on various species. Furthermore, when testosterone is replaced through hormone therapy in these castrated animals, the amount of aggression increases and is restored to its original pre-castration level. Taken together, this seems to present a strong argument for the role of testosterone in aggression. However, the story does not end here: if we are to suppose that testosterone does in fact lead to aggressive behavior we must then necessarily ask how and why it does. In doing so, we might just find that the original supposition falls through (Bland 2004).

Testosterone exerts its hormonal and behavioral effects upon interaction with androgen receptors (i.e., when converted into 5-alpha-dihydrotestosterone) or with estrogen receptors (i.e., when converted into estradiol by aromatase) (Simpson 2001). According to some, there exists a "critical time period" (i.e., during development) when testosterone serves to "sensitize" particular neural circuits in the brain. Presumably, this sensitization allows for the effects of testosterone that manifest in adulthood. A recent theory builds upon this story, adding the idea that almost immediately after birth, testosterone leads to the establishment of an "androgen-responsive system" in males. It is presumed that a similar androgen system is set-up in females, although a greater exposure to androgens is required to induce male-like fighting.

Although not the primary function of most hormones, neural activity can be modulated as a result of their presence. For example, it has been shown that some hormones can modify cell permeability and therefore have a crucial impact on ion concentration, membrane potential, synaptic transmission and thus neural communication and behavioral outcomes (Simpson 2001). More specifically, when a hormone such as testosterone acts on a target neuron, the amount of neurotransmitter that is released is significantly affected. For example, it has been suggested (i.e., with experimental data) that testosterone acts on serotonergic synapses and lowers the amount of serotonin available for synaptic transmission. This is important when coupled with the fairly well accepted idea that the presence of serotonin serves to inhibit aggression, as shown convincingly in studies performed on male rhesus monkeys: serotonin reuptake inhibitors such as Fluoxetine and several other antidepressants lead to a significant decrease in aggression in both monkeys and humans.

In non-human animals, the relationship between testosterone and aggression (where aggression is operationalized through observable aggressive behavior) has been demonstrated through correlational and experimental studies, involving manipulation of testosterone levels through castration and injection of testosterone. Results overwhelmingly indicate that testosterone and aggression are related (Turner 1994).

Experimental results further suggest that testosterone is a causal factor in aggressive nonhuman animal behavior. Castration of male mice (vom Saal 1983) and lizards (Greenberg, Crews 1983) results in a decrease in aggressive behavior, regardless of how aggression is measured (vom Saal 1983).

The term aggression has been defined as "a response that delivers noxious stimuli to another person" (Buss 1961). In animals, however, there are various forms of aggression classified into predatory, inter-male, fear-induced, irritable, territorial, maternal and instrumental (Moyer 1968). Androgens have been found to affect only certain forms, for example, inter-male aggression which can be illustrated by the resident-intruder test. In contrast, predatory aggression is entirely independent of androgens (Bermond, Mos, Meelis 1982). Therefore only the forms of aggression that have been found to have a link with testosterone facilitation will be discussed.

The classical hormone removal and replacement experiment approach has shown a definite link between testosterone and aggression in animals. In general, castration leads to a decrease in aggression whilst replacement of testosterone restores the behavior. However, differences in the effects induced by testosterone have become apparent between males and females. Different regions in the brain modulate different hormone-dependent aggression (Albert, Jonik, Walsh 1992) and females require longer exposure to androgens after ovariectomy to induce male-like behavior (Simon, Whalen, Tate 1985).

Aggression in females, like in males, appears to be facilitated by testosterone in a dose-dependent manner (Edwards 1969). In one study, ovariectomized female rats were given daily injections of testosterone, estradiol or placebo. It was found that testosterone increased aggressiveness, measured by the frequency of fighting, whereas estradiol or placebo had little effect (van de Poll et al. 1988).

HOW DOES TESTOSTERONE CAUSE AGGRESSION?

Testosterone acts as a prohormone which when converted into 5-alpha-dihydrotestosterone (5a-DHT) acts on androgen receptors or when converted into estradiol by the enzyme aromatase, acts on estrogen receptors. There is overwhelming evidence that most of the effects of testosterone in mediating aggression occur after aromatization (Schlinger, Callard 1990). For example, testosterone induced aggression is concurrent with an elevated level of aromatization and nuclear estrogen receptor activity in the hypothalamic/preoptic area. Treatment with an aromatase inhibitor blocked this aggression and lowered nuclear activated estrogen receptors (Schlinger, Callard 1989; Naftoli et al. 1990). Furthermore the intensity of aggressive behavior was directly correlated with the aromatase activity ($p < 0.02$) in the posterior hypothalamus (Schlinger, Callard 1989).

Testosterone also has effects that are manifested early in life. The neonatal organizing actions of testosterone are achieved by stimulating cell growth and differentiation in the preoptic area, ventromedial hypothalamus and amygdala, and dendritic branching in the preoptic area and the hypothalamus (Naftoli et al. 1990). For example, authors have suggested that testosterone increases the size of the granule cell layer in the dentate gyrus (origin of hippocampal mossy fibres) and that these effects occur during a 'critical time period' (Guillot, Roubertoux, Crusio 1994; Sluyter et al. 1994).

Persky, Smith and Basu (1971) obtained a regression equation for testosterone production rate and four psychological measures of aggression and hostility, which accounted for 82 per cent of the variance in production rate for the younger men ($N = 18$) in their sample. The measures were the two factors I and II of the Buss-Durkee Hostility Inventory, adjective check-list measures and an anxiety scale which also measured aggressive feelings. For the older men (who showed a much smaller production rate), the relationship was not significant. Young and Ismail (1979) measured a number of psychological and physiological variables (including testosterone) before and after a four-month exercise programme in 58 men covering a wide age range (21-61 years). A stepwise regression carried out prior to the exercise programme found that several psychological variables, the most powerful of which was neuroticism, predicted testosterone levels. Among these was aggressiveness (factor E of the 16PF).

In females, there is also an androgen-sensitive pathway, although a greater exposure to androgens is required to induce male-like fighting behavior. Evidence to support this comes from the finding that 400 mg of testosterone propionate will effectively organize female aggression at 0-2 hours after birth but it will not at two days of age. However if 600 mg is administered at this later stage, the treatment is effective (Peters, Bronson, Whitsett 1972). Furthermore, adult females are completely insensitive to the aggression-promoting effects of estrogens seen in males.

Therefore there appears to be a sensitive period when the differentiation of aggression with hormones is most likely, i.e. shortly after birth, but the period can be extended by increasing the hormone dosage. Furthermore, the results indicate that hypothalamic and associated brain mechanisms become less sensitive to exogenous androgen with time after castration (Motelica-Heino, Edwards, Roffi 1993), most likely due to decreased sensitivity of the receptors with age (da Vanzo et al. 1986). There is, however, some conflicting evidence to suggest that the critical time period is not essential to elicit aggression in adulthood. For example, males castrated on day 0 were found to show aggression in adulthood in response to testosterone, however larger doses and often a longer duration of treatment were required (Edwards 1969).

Testosterone has also been found to influence the density of $GABA_A$ receptors. Testosterone-treated rats have a decreased density of $GABA_A$ receptors in several brain regions (Earley, Leonard 1976) and several studies have implicated low levels of GABA (gamma amino-butyric acid) with aggression (Cunha et al. 1991; Guillot, Chapouthier 1996). Coincidently, a role for GABAergic inhibition has been implicated in odor coding and in particular $GABA_A$ antagonists caused lowering of the response threshold to odors (Guillot, Chapouthier 1996; Duchamp-Viret, Duchamp 1993). Therefore high-attacking animals would have a better perception of the olfactory cues leading to rapid recognition of the opponent.

Finally, testosterone has been found to suppress dopamine turnover in the anterior hypothalamus of male rats (Simpkins, Kalra, Kalra 1983) which was thought to be involved in androgen-dependent aggression, although studies tend to support a positive relationship between central dopamine function and aggression (Coccaro 1996). There have also been suggestions that acetylcholine and glutamate are involved in testosterone-mediated aggression.

Research into human forms of behavior such as aggression is complicated by the complex manner in which humans tend to behave. For example, studies have found that aggressive encounters are influenced by learning, i.e. the outcome of the first encounter influenced subsequent fights (Chase 1982). There is also evidence that aggression is, in itself, rewarding. For example, when animals with lateral hypothalamic electrodes were allowed to control the stimulation, they pressed the levers with high frequencies suggesting the presence of 'positive' feelings (van de Poll et al. 1988). Interestingly, self-stimulation rates were decreased when the animals were castrated and increased again after hormone substitution.

Other research has indicated that testosterone may be correlated with aggressive motives and competitiveness rather than violence *per se*. Serotonin function on the other hand may function to limit aggression to an appropriate time, setting and intensity. Overall the results indicate that while subjects with high levels of testosterone exhibit more aggression, the aggressive encounters are stopped before they escalate into dangerous forms of aggression (Highley, Mehlman, Poland 1996). Other factors implicated in aggression include involvement of the Y chromosome (Carlier et al. 1990; Rudd, Galal, Casey 1968), alcohol (Winslow, Ellingboe, Miczek 1988) and the role of olfaction (Wood, Newman 1995).

CORRELATION OF HANDGRIP STRENGTH WITH HUMAN SEXUAL BEHAVIOR

The relationship between testosterone and aggression linked to this group of several features and traits in human physique and cognition - to display masculinity and fitness - emerged as a result of sexual selection (competition between males for limited resources).

Handgrip strength (HGS) is a sex different indicator of muscular strength in general, persistent among several ethnic groups (Monti-Bloch et al. 1998).The fact that HGS is male--specific can indicate that its evolution is related to sexual behavior (Fink, Neave, Seydel 2007). The measurements of HGS in human males appear to be positively correlated with more promiscuous sexual behavior, masculinity and predicting physical and social dominance, characteristics driven by testosterone levels (Gallup, White, Gallup 2007). Males with higher HGS show a higher number of sex partners and start to have sexual relationships at an earlier age while the same doesn't occur in females (Shoup, Gallup 2008; Monti-Bloch et al. 1998; Fink, Neave, Seydel 2007).

In females, HGS doesn't have an effect on promiscuity behaviors, probably because HGS is dependent on testosterone levels, which are lower in women (Shoup, Gallup 2008; Monti-Bloch et al. 1998). Although Petralia and Gallup (2001) suggested that females can suffer variation in HGS in different phases of his sexual cycle, specifically in fertile period. At this period females are less likely to engage in risk taking behaviors and their grip strength has been proved to increase when confronted with sexual assaults. Women are more likely to conceive in the ovulatory phase, needing more defense strategies against sexual assaults that would be highly disadvantageous at this particular period (Petralia, Gallup 2001).

Furthermore, females also can perceive male's HGS, associating it with dominance but not always with attractiveness (Shoup, Gallup 2008; Monti-Bloch et al. 1998). Supporting this assumption, females were shown to be more likely to prefer more dominant males for short-term relationships, especially during the fertile phase of their menstrual cycle, and engage in long-term relationships with less masculine males (Fink, Neave, Seydel 2007). In this context the female's preference tend to assure their maximum fitness. Thus, although females recognize dominant males they tend to avoid them in long-term relationship because - despite the physical and social dominance - as they tend to engage in more extra-pair copulations, providing less parental investment and tend to be more aggressive which can be threatening for the female's fitness (Fink, Neave, Seydel 2007; Frederick, Haselton 2007). On the other hand, males with lower HGS are more likely to be loyal and display parental investment but they are perceived by females as weak and submissive, not being a great choice to assure the genetic quality of their offspring (Frederick, Haselton 2007). Consequently females are more likely to recognize average males as more attractive, since they are predictable indication to maximum female's fitness (Fink, Neave, Seydel 2007; Frederick, Haselton 2007).

Humans have a reliable sense of vision and the existence of neural mechanisms specialized in facial recognition is known, which indicates the importance of recognizing important fitness cues in faces (Rhodes, Simmons, Peters 2005). HGS is strongly hereditable (reported at 65%) and is closely linked to testosterone levels, being a reliable indicator of fitness quality in males, underlying health, longevity and semen quality (Gallup, White, Gallup 2007; Shoup, Gallup 2008, Solera et al. 2003). Since females tend to perceive males with higher HGS favorably, it could be an honest indicator of good genes (Gallup, White, Gallup 2007; Monti-Bloch et al. 1998; Frederick, Haselton 2007). Testosterone is an immunosuppressant hormone that also controls secondary sexual traits development. Males displaying strong HGS and other secondary sexual traits must have a good genetic quality since they carry a potentially costly handicap (in eventually decreased immunity). Females are likely to favor such males because these traits will be inherited by their offspring, enhancing their reproductive success in later generations (Frederick, Haselton 2007).

However, having in mind the previous assumption, women do not perceive more masculine males as more attractive; the good genes hypothesis doesn't seem to be the evolutionary reason for HGS being perceived well by females. In a variety of animals, males tend to engage in intrasexual competition. Shoup and Gallup (2008) proposed that this intrasexual competition could be responsible for the selection of HGS in human males.

The handshake is a common greeting among men and culturally very widespread. Following these authors, this daily gesture could be a way of judging the aggression scale of the rival males, since higher HGS is related to higher aggression and vitality in males. Thus, the handshake can allow males to have prior knowledge about fitness of their competitors, permitting accurate decisions regarding the competitive strategies to adopt in future interactions. Besides, if this assumption is correct, the grip strength would be positively selected among males in intrasexual competition which would explain HGS correlation with sexual and aggressive behavior (Monti-Bloch et al. 1998).

CONCLUSION

In this article we overviewed the several correlations between the handgrip strength and psychosomatic traits in humans. It is one of the best indicators of the testosterone levels in males and, therefore, it's a prime trait to measure and ascertain correlations and experiments with other traits that are intimately connected to the testosterone levels during neonatal, adolescence and post-adolescence ontogeny of male individuals. These traits are all intertwined together to signal cues about aggressiveness (and, thus, relations of dominance/submission and resource-holding capabilities), body-type morphology and facial structure (in its display of masculinity, handsomeness, health status and vitality).

There are, however, a few critics and points to consider in these studies. Further research is necessary to exactly understand how testosterone influences aggressiveness, competitiveness and actual physical violence to other conspecifics. Being the core of all the traits here analyzed, it is crucial to comprehend the androgens' role in humans. Others criticize how certain studies conduct their research by isolating the many variables, which could affect the results since these variables are never acting in an isolated fashion (Gallup, White, Gallup 2007; Henderson, Anglin 2003).

Finally, other studies pertaining to measure attractiveness of morphology must gather more data from different cultural backgrounds since nowadays the mass media and globalization are homogenizing what is considered aesthetically beautiful in the body-type and facial structure of human individuals and these considerations may be completely different than when humans appeared in the Pleistocene (Henderson, Anglin 2003).

REFERENCES

Albert, D. J. – Jonik, R. H. – Walsh, M. L. (1992): Hormone-dependent aggression in male and female rats: experiential, hormonal, and neural foundations. *Neuroscience and Biobehavioural Reviews*, 16: 177-192.

Archer, J. (1991): The influence of testosterone on human aggression. *British Journal of Psychology*, 82, 1–28.

Bermond, B. – Mos, J. – Meelis, W. et al. (1982): Aggression induced by stimulation of the hypothalamus: effects of androgens. *Pharmacology, Biochemistry and Behavior*, 16: 145-155.

Bland, J. (2004): About Gender: Hormones is Context - Testosterone and Aggression. Retrieved from *http://www.gender.org.uk/about/06encrn/63_aggrs.htm*, 20.8. 2013.

Buss, A. H. (1961): *The Psychology of Aggression*. New York: Wiley.
Carlier, M. – Roubertoux, P. L. – Kottler, I. – Degrelle H. (1990): Y chromosome and aggression in strains of laboratory mice. *Behavior Genetics*, 20: 137-156.
Coccaro, E. (1996): Neurotransmitter correlates of impulsive aggression in humans. In: C., Ferris – T., Grisso (Eds). *Understanding Aggressive Behaviour in Children*. Annals of the New York Academy of Sciences, 794: 82-89.
Cunha, G. R. – Cooke, P. S. – Bigsby, R. – Brody, J. R. (1991): Ontogeny of sex steroid receptors in mammals. In: M., Parker (Ed). *Nuclear Hormone Receptors: Molecular Mechanisms, Cellular Functions, Clinical Abnormalities*. London: Academic Press, pp. 235-268.
da Vanzo, J. P. – Chamberlain, J. K. – Garris, D. R. – Swanson, M. S. (1986): Regional [3H] testosterone uptake in the brain of isolated nonaggressive mice. *Brain Research*, 369: 224-230.
Duchamp-Viret, P. – Duchamp, A. (1993): GABAergic control of odorinduced activity in the frog olfactory bulb: possible GABAergic modulation of granule cell inhibition action. *Neuroscience*, 56: 905-914.
Earley, C. J. – Leonard, B. E. (1976): The effect of testosterone and cyproterone acetate on the concentration of gammaaminobutyric acid in brain areas of aggressive and nonaggressive mice. *Pharmacology, Biochemistry and Behavior. Psychosomatics*, 17: 138-142.
Edwards, D. A. (1969): Early androgen stimulation and aggressive behavior in male and female mice. *Physiology and Behavior*, 4: 333-338.
Fink, B. – Neave, N. – Seydel, H. (2007): Male facial appearance signals physical strength to women. *American Journal of Human Biology*, 19: 82–87.
Frederick, D. – Haselton, F. (2007): Why is muscularity sexy? Tests of the fitness indicator hypothesis. *Personality and Social Psychology Bulletin*, 33: 1167-1184.
Gallup, A. – White, D. – Gallup, G. (2007): Handgrip strength predicts sexual behavior, body morphology, and aggression in male college students. *Evolution and Human Behavior*, 28: 423-429.
Greenberg, N. – Crews, D. (1983): Physiological ethology of aggression in amphibians and reptiles. In: B. Svare (Ed.), *Hormones and aggressive behavior*. New York: Plenum, pp. 469–506.
Guillot, P. V. – Chapouthier, G. (1996): Olfaction, GABAergic neurotransmission in the olfactory bulb, and intermale aggression in mice: modulation by steroids. *Behavior Genetics*, 26: 497-504.
Guillot, P. V. – Roubertoux, P. L. – Crusio, W. E. (1994): Hippocampal mossy fiber distributions and intermale aggression in seven inbred mouse strains. *Brain Research*, 660: 167-169.
Haselhuhn, M. – Wong, E. (2012): Bad to the bone: facial structure predicts unethical behavior. *Proceedings of the Royal Society*, 279: 571-576.
Henderson, J. – Anglin J. (2003): Facial attractiveness predicts longevity. *Evolution and Human Behavior*, 24: 351-356.
Higley, J. D. – Mehlman, P. T. – Poland, R. E. et al. (1996): CSF testosterone and 5-HIAA correlate with different types of aggressive behaviors. *Biological Psychiatry*, 40: 1067-1082.
Chase, I. D. (1982): Dynamics of hierarchy formation: the sequential development of dominance relationships. *Behavior*, 80: 218-238.
Mazur, A. – Booth, A. (1998): Testosterone and dominance in men. *Behavioral and Brain Sciences*, 21, 353–397.
Mazur, A. (1983): Hormones, aggression and dominance in humans. In: B. Svare (Ed.), *Hormones and aggressive behavior*. New York: Plenum, pp. 563–576.
Monti-Bloch, L. – Diaz-Sanchez, V. – Jennings-White, C. – Berliner, D. L. (1998): Modulation of serum testosterone and autonomic function through stimulation of the male human vomeronasal organ (VNO) with pregna-4,20,diene-3,6-dione. *Journal of Steroid Biochemistry and Molecular Biology*, 65: 237-242
Motelica-Heino, I. – Edwards, D. A. – Roffi J. (1993): Intermale aggression in mice: does hour of castration after birth influence adult behaviour? *Physiology and Behavior*, 53: 1017-1019.
Moyer, K. E. (1968): Kinds of aggression and their physiological basis. *Communications in Behavioural Biology*, 2: 65-87.
Naftoli, F. – Garcia-Segura, L. M. – Keefe, D. et al. (1990): Estrogen effects on the synaptology and neural memebranes of the rat hypothalamic arcuate nucleus. *Biology of Reproduction*, 42: 21-28.
Persky, H. – Smith, K. D. – Basu, G. K. (1971): Relation of psychologic measures of aggression and hostility to testosterone production in man. *Psychosomatic Medicine*, 33, 265-277.
Peters, P. J. – Bronson, F. H. – Whitsett, J. M. (1972): Neonatal castration and intermale aggression in mice. *Physiology and Behaviour*, 8: 265-268.
Petralia, S. – Gallup, G. (2001): Effects of a sexual assault scenario on handgrip strength across the menstrual cycle. *Evolution and Human Behavior*, 23: 3–10.
Rhodes, G. – Simmons, L. – Peters, M. (2005): Attractiveness and sexual behavior: Does attractiveness enhance mating success? *Evolution and Human Behavior*, 26: 186–201.
Rudd, B. T. – Galal, O. M. – Casey, M. D. (1968): Testosterone secretion rates in normal males and males with an XYY complement. *Journal of Medical Genetics*, 5: 286-288.
Sell, A. – Cosmides, L. – Tooby, J. – Sznycer, D. – Rueden, C. – Gurven, M. (2009): Human adaptations for the visual assessment of strength and fighting ability from the body and face. *Proceedings of the Royal Society*, 276: 575-584.
Shoup, M. – Gallup, G. (2008): Men's faces convey information about their bodies and their behavior: what you see is what you get. *Evolutionary Psychology*, 6 (3): 469-479.
Schlinger, B. A. – Callard, G. V. (1989): Aromatase activity in quail brain: correlation with aggressiveness. *Endocrinology*, 124: 437-443.
Schlinger, B. A. – Callard, G. V. (1990): Aromatization mediates aggressive behavior in quail. *General and Comparative Endocrinology*, 79: 39-53.
Simon, N. – McKenna, S. – Lu, S. – Collager-Clifford, A. (1996): Development and expression of hormonal systems regulating aggression. *Annals of the New York Academy of Sciences*, 794, 8–17.
Simon, N. – Whalen, R. – Tate, M. (1985): Induction of male-typical aggression by androgens but not estrogens in adult female mice. *Hormones and Behavior*, 19: 204-212.
Simpkins, J. – Kalra, S. – Kalra, P. (1983): Variable effects of testosterone on dopamine activity in several microdissected regions in the preoptic area and medial basal hypothalamus. Endocrinology, 112: 665-669.
Simpson, K. (2001): The Role of Testosterone in Aggression. *McGill Journal of Medicine*, 6, 32-40.
Sluyter, F. – Jamot, L. – van Oortmerssen, G. A. – Crusio, W. E. (1994): Hippocampal mossy fiber distributions in mice selected for aggression. *Brain Research*, 646: 145-148.
Solera, C. – Núñez, M. – Gutiérrez, R. – Núñez et al. (2003): Facial attractiveness in men provides clues to semen quality. *Evolution and Human Behavior*, 24: 199–207.
Stirrat, M. – Perrett, D. (2010): Valid facial cues to cooperation and trust: male facial width and trustworthiness. *Psychological Science*, 21: 349-354.
Stirrat, M. – Stulp, G. – Pollet, T. (2012): Male facial width is associated with death by contact violence: narrow-faced males are more likely to die from contact violence. *Evolution and Human Behavior*, 33: 551-556.
Turner, A. K. (1994): Genetic and hormonal influences on male violence. In: J. Archer (Ed.), *Male violence*. New York: Routledge, pp. 233–252.
van de Poll, N. E. – Taminiau, M. S. – Endert, E. – Louwerse, A. L. (1988): Gonadal steroid influence upon sexual and aggressive behaviour of female rats. *International Journal of Neuroscience*, 41: 271-286.
vom Saal, F. (1983): Models of early hormonal effects on intrasex aggression in mice. In: B. Svare (Ed.), *Hormones and aggressive behavior*. New York: Plenum, pp. 197–222.
Winslow, J. T. – Ellingboe, J. – Miczek, K. A. (1988): Effects of alcohol on aggressive behavior in squirrel monkeys: influence of testosterone and social context. *Psychopharmacology*, 95: 92-98.
Wood, R. I. – Newman, S. W. (1995): Hormonal influence on neurons of the mating behavior pathway in male hamsters. In: P., Micevych – R. P., Hammer (Eds). *Neurobiological Effects of Sex Steroid Hormones*. Cambridge: Cambridge University Press, 3-39.
Young, R. J. – Ismail, A. H. (1979): Prediction of serum testosterone before and after an exercise program using physiological and personality variables. *Journal of Human Ergology*, 8, 29-38.

AUTHORS

Cunha, Daniela Patrícia Miranda, University of Coimbra, Coimbra, Portugal,
E-mail: danielapmcunha@gmail.com

Monteiro, Filipe Afonso Gonçalves, University of Coimbra, Coimbra, Portugal,
E-mail: ftuuky@hotmail.com

Hamarat, Yasin, Bülent Ecevit University, Zonguldak, Turkey
E-mail: 404566@mail.muni.cz

Corresponding author

Čuta, Martin (18.1.1979, Brno), works as an assistant professor at the Department of Anthropology, Faculty of Science, Masaryk University (Brno). He focuses his research on physical anthropology – growth and development, functional anthropology, sports anthropology, anthropometry. His teaching activities include courses of anatomy for anthropologists, methodological and also introductory courses in anthropology.

Contact: Mgr. Martin Čuta, PhD.
Dept. of Anthropology, Faculty of Science, Masaryk University
Vinařská 5, 603 00 Brno, E-mail: cuta@sci.muni.cz