

# Why is digit ratio correlated to sports performance?

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Second to fourth digit ratio is the ratio of second to fourth digit length. It has been known that digit ratio is sexually dimorphic in humans, such that males tend to have lower digit ratio (longer fourth digits relative to second digits) than females. Digit ratio is thought to be a biomarker of the balance between fetal testosterone (FT) and fetal estrogen (FE) in a relatively narrow developmental window at the end of the first trimester of pregnancy. On the contrary, the relationships between digit ratio and levels of sex steroids in adults are not clear. Most correlational studies

between digit ratio and adult sex steroids have revealed that this association is statistically not significant. However, for many years, a lot of researches showed negative relationships between digit ratio and sports performance such as rugby, surfing, rowing, sprinting, endurance, and hand grip strength. Here, we discuss possible mechanisms about the relationships between digit ratio and sports performance.

**Keywords:** Digit ratio, Sports, Testosterone

## INTRODUCTION

Second to fourth digit ratio is the ratio of second to fourth digit length (Fig. 1). Males tended to have lower digit ratio (longer fourth digits relative to second digits) than females (Phelps, 1952; Fig. 2), and mean digit ratio did not change significantly with age (Manning, 2002).

To date, a lot of researches showed negative relationships between digit ratio and sports performance such as rugby, surfing, rowing, sprinting, endurance, and hand grip strength (Bennett et al., 2010; Hönekopp and Schuster, 2010; Hull et al., 2015; Kilduff et al., 2011; Longman et al., 2011; Manning and Hill, 2009; Manning et al., 2007; Ranson et al., 2015). For example, low right digit ratio is a predictor of high rugby performance (Bennett et al., 2010). Low right digit ratio correlates to high surfing ability in men (Kilduff et al., 2011). Significant negative correlations were observed between 2,000 m ergometer performance (rowing) and male digit ratios (Longman et al., 2011). Females with smaller digit ratios also rowed substantially faster than females with larger digit ratios (Hull et al., 2015). Low digit ratio is implicated in high sprinting speed, endurance and hand grip strength in boys (Ranson et al., 2015).


These findings showed that low digit ratio possibly linked to better sports performance. Thus, we discuss possible mechanisms about the relationships between digit ratio and sports performance.

## POSSIBLE MECHANISMS

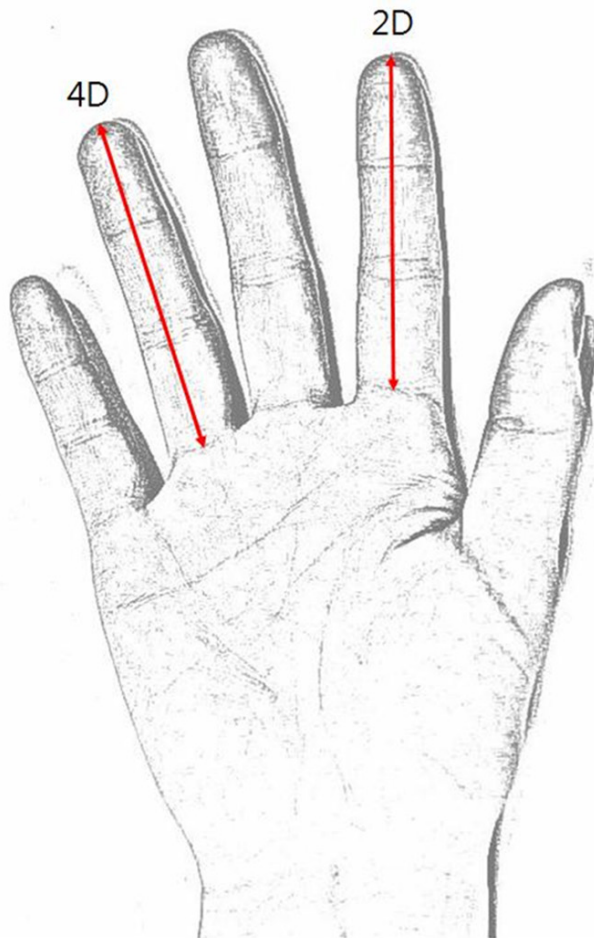
Most studies about digit ratio are based on the relationships between prenatal sex steroids and sexually dimorphic physical and behavioral traits. In humans, several studies of congenital adrenal hyperplasia (CAH) and digit ratio have shown relationships between low digit ratio and CAH (Hönekopp and Watson, 2010). On the contrary, in Klinefelter syndrome, digit ratio is significantly higher than that of the normal population (Manning et al., 2013). A tendency of high digit ratio has also been found in individuals with androgen insensitivity (Berenbaum et al., 2009).

## DIGIT RATIO AND PRENATAL SEX STEROIDS

Lutchmaya et al. (2004) acquired both fetal testosterone (FT) and fetal estrogen (FE) concentrations from amniotic fluid sam-

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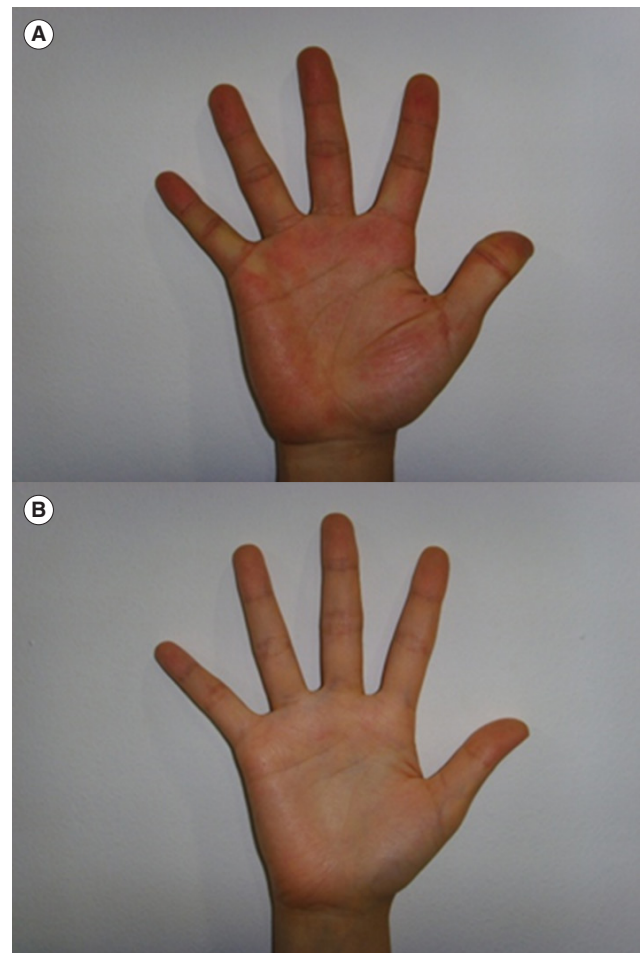


**Fig. 1.** Digit ratio. Digit ratio =  $2D/4D$ .

ples (Lutchmaya et al., 2004). They revealed that digit ratio of neonates was related to a balance of FT and FE, such that low digit ratio were linked to high FT and low FE (Manning et al., 1998; Manning, 2002). In fetuses, the difference in digit ratio between sexes is found as early as the end of the first trimester (Galis et al., 2010; Malas et al., 2006). These support that FT levels are sexually dimorphic, that is, male fetuses have higher testosterone than female fetuses. Therefore, the prenatal determination of the sexual dimorphism in digit ratio represents that the sex difference in digit ratio reflects levels of prenatal sex steroids.

## RIGHT-LEFT DIGIT RATIO

Several studies suggested that right digit ratio is more sensitive to prenatal sex steroids than left digit ratio (Manning, 2002; Manning et al., 1998). In humans, right digit ratio showed stron-



**Fig. 2.** Digit ratio of male vs. female. (A) Male; digit ratio =  $2D/4D = 7.0 \text{ cm}/7.5 \text{ cm} = 0.93$ . (B) Female; digit ratio =  $2D/4D = 7.5 \text{ cm}/7.5 \text{ cm} = 1.00$ .

ger relationships with testosterone and sperm numbers than did left digit ratio (Manning et al., 1998). More recently, Hönekopp and Watson (2010) showed that the sex difference in right digit ratio was greater than that of left digit ratio (Hönekopp and Watson, 2010). Zheng and Cohn (2011) revealed that digit ratio of the right paw is more sensitive to FT and FE than digit ratio of the left paw (Manning, 2011; Zheng and Cohn, 2011). Thus, it has been suggested that right-left digit ratio ( $Dr-l$ ) might be an additional negative indicator for FT and a positive indicator for FE (Kilduff et al., 2013a; Kilduff et al., 2013b).

## DIGIT RATIO AND ADULT SEX STEROIDS

These associations of digit ratio with prenatal sex steroids might assume that digit ratio is, in a sense, related with adult sex steroids through its links with prenatal sex steroids. Actually, re-

searchers have reported that in adults, digit ratio is associated with a lot of morphological and behavioral traits (Manning, 2002; Manning, 2009). However, a few studies have shown a negative correlation between digit ratio and testosterone (Coco et al., 2011; Manning et al., 1998; Perciavalle et al., 2013) and a positive correlation with estrogen (Manning et al., 1998; McIntyre et al., 2007). In most studies with the normal (nonclinical) population, digit ratio is not associated with adult sex steroid levels (Hönekopp et al., 2007; Manning et al., 2004; Muller et al., 2011).

## COMPETITION AND SUDDEN SURGE IN TESTOSTERONE

Several studies showed that competition may lead to sudden surge in testosterone, that is, testosterone levels tend to show sudden surge in response to aggressive (Elias, 1981) and sexual (Escasa et al., 2011) encounters and to competitive sports such as soccer (Neave and Wolfson, 2003). Two studies have considered digit ratio and sudden surge of testosterone induced by exercise or by an aggressive video (Kilduff et al., 2013a; Kilduff et al., 2013b). They showed that low digit ratio is related to high aggression scores after the aggressive video, and that in particular, the relationship was strong in participants showing the highest sudden surge in testosterone (Kilduff et al., 2013b). These studies suggested that digit ratio is not related to testosterone at resting situations but is associated with sudden surge of testosterone at competitive situations. Thus, it has been assumed that low digit ratio is associated with performance in many competitive sports. Actually, the two studies showed that good muscular performance results from such sudden surge of testosterone (Crewther et al., 2011; Cook et al., 2014).

## DIGIT RATIO AND COMPETITIVE SPORTS

Evidence of relationships between digit ratio and competitive sports is driven from the association between low digit ratio and marked sudden surge of testosterone after competition. It has been known that low Dr-I is related to high performance in elite rugby union players (Bennett et al., 2010). And, low Dr-I is also a predictive factor of high sudden surge of testosterone. And, low digit ratio is also linked to high levels of performance in females (Hönekopp and Schuster, 2010). These correlations may in part explain the link between low digit ratio and competitive sports (Ribeiro et al., 2016).

## DIGIT RATIO AND AGGRESSION

Aggression is important in many sports. And, low digit ratio has been correlated with high physical aggression. The two studies showed that low digit ratio predicts high aggression at competitive situations (Millet, 2010; Millet and Dewitte, 2007). Another example is the intensely competitive environment of short-term financial trading. It was reported that digit ratio is negatively related to financial success (Coates et al., 2009).

## DIGIT RATIO AND PREFERENCE FOR HIGH-RISK SPORTS

Boxing and judo are considered to be high-risk sports. Kociuba et al. (2016) found that in female participants, the judo/boxing group had significantly lower digit ratio than the aerobics group. This suggests that voluntary choice of participation in a sport discipline by women could be linked to the organizational effect of intrauterine testosterone exposure during prenatal growth (Kociuba et al., 2016).

## DIGIT RATIO AND MAXIMAL OXYGEN UPTAKE

Significant negative correlations were observed between 2,000 m ergometer performance (rowing) and male digit ratios. This means that digit ratio is a predictor of ability in rowing, a sport which requires both cardiovascular efficiency and high power output in males (Longman et al., 2011). Hill et al. (2012) revealed the relationships between digit ratio and cardiovascular efficiency. Low right-left digit ratio is associated with high maximal oxygen uptake ( $VO_{2max}$ ), high velocity at  $VO_{2max}$ , and high maximum lactate concentration in a sample of teenage boys. This means that low right-left digit ratio is linked to performance in some sports because it is a proxy of high sensitivity to prenatal and maybe also circulating testosterone and high  $VO_{2max}$  (Hill et al., 2012).

## CONCLUSIONS

Most correlational studies between digit ratio and adult sex steroids have revealed that the association is statistically not significant. However, for many years, a lot of researches showed negative relationships between digit ratio and sports performance such as rugby, surfing, rowing, sprinting, endurance, and hand grip strength. As possible mechanisms about the relationships between

digit ratio and sports performance, digit ratio is suggested to correlate with sudden surge of testosterone under competition. In consequence, low digit ratio may be a predictor of high performance in sports through high aggression, preference for competitive sports, and  $VO_{2max}$ . We think that further studies are needed to clearly reveal whether the relative levels of FT and FE have organizing effects on the adult endocrine system.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

## ACKNOWLEDGMENTS

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