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ACE /VDR gene polymorphisms and bioelectrical impedance analysis in predicting athletic performances of Italian young soccer players

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Running head: ACE and VDR gene polymorphisms in soccer players.

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ABSTRACT

We evaluated the association between two genetic polymorphisms known to be involved in fitness and performance, and anthropometric features, body composition and athletic performances in young male soccer players with the goal of identifying genetic profiles that can be used to achieve maximal results from training. One hundred twenty five medium-high level male soccer players were genotyped for Angiotensin Converting Enzime (ACE) I/D, and Vitamin D receptor (VDR) *Fok*I gene polymorphisms and scored for anthropometric measurements, body composition and athletic performance. Body mass index, fat mass, fat free mass, resistance, reactance, impedance, phase angle and body cell mass were measured. Athletic performance was evaluated by: squat jump, counter movement jump, 2 kg medicine ball throw, 10 and 20 meter sprint time. We observed that the homozygous *ff* genotype of the VDR gene was significantly more represented in young soccer players than in a matched sedentary population. Values of reactance and phase angle were differently distributed in ACE and VDR genotypes with high mean values in subjects with DD (ACE) and FF (VDR) genotypes. No correlation was observed between ACE or VDR genotypes and 2 kg medicine ball throw, 10 and 20 meter sprint times. The ID genotype of ACE was associated with the best performances in squat jump and counter movement jump. Our results suggest that determination of ACE and VDR genotypes might help select those young athletes harbouring the most favorable genetic potential to succeed in soccer.

Keywords: genetics, athletic performance, soccer, training.

INTRODUCTION

It is widely accepted that athletic performance is the result of a combination of the most favorable genotypes with exposure to highly specialized training environments (1). Among the genes involved in predicting athletic phenotype and individual response to training, the Angiotensin Converting Enzyme (ACE) and the Vitamin D Receptor (VDR) genes play a crucial role because of their involvement in a variety of performance-related functions (2, 3). In previous studies, polymorphisms of the ACE gene were associated with cardiovascular and muscle physiology as well as with a number of performance-related traits typical of professional athletes (4). Also the polymorphisms of the VDR gene were associated with differences in individual response to training (5) thanks to the pivotal role of vitamin D in a number of metabolic pathways related to physiology of the cardiovascular system and muscle contraction (6).

Even though genetics might be the tool of the future to predict athletic performance and design individualized training, as of today evaluation of physical response to exercise and training is still routinely determined by laboratory and field tests such us jump test (Squat Jump - SJ, Counter Movement Jump - CMJ), medicine ball throw, and sprint tests. Field tests provide results that are specific for each sport and are regarded by many as more accurate than laboratory tests (7, 8). Anthropometric characteristics related to physiological characteristics (9) and body composition (10), are also commonly measured in order to have a more complete assessment of nutritional and health status. Body composition is commonly evaluated by bioelectrical impedance analysis that estimates the size of different body compartments such as fat free mass (FFM), fat mass (FM), body cell mass (BCM) (11, 12). Furthermore, some “pure” bioelectrical parameters such as resistance (R), reactance (*Xc*), and phase angle (PA), without the use of regression equations specific for population, are considered valid tools to assess the nutritional and metabolic status of athletes as well as to estimate the changes of soft tissue hydration (12, 13, 14, 15, 16, 17, 18).

In this study we investigated the association between ACE and VDR gene polymorphisms, bioelectrical impedance analysis parameters, anthropometric features and athletic performance in young male soccer players; from a gene analysis perspective, the goal of this study is to identify genetic profiles that are associated with performance and can be used to select the young athletes harbouring the most favorable genetic potential to succeed in soccer and to train them according to their characteristics.

METHODS

Experimental Approach to the Problem

The distribution of ACE and VDR gene polymorphisms in a group of young Italian medium-high-level soccer players was determined, and the results were compared to the distributions of such polymorphisms in sedentary control populations. Furthermore, the association between anthropometric features, bioelectrical impedance analysis parameters, field physical tests and genotypes within the group of young soccer players was evaluated by means of statistical analysis.

Subjects

One hundred twenty five medium-high level soccer players (Caucasian males under 17 years of age) were enrolled by the Training Methodology and Applied Biomechanics' Laboratory, Technical Division; *Federazione Italiana Gioco Calcio* (the Italian soccer federation) *FIGC* of Coverciano, Firenze, Italy. The study was performed in accordance with the required ethical standards. Written informed consent to participate in the study was obtained from the interested subject and from a parent or a tutor according to current Italian law; signed informed consent forms are archived at the Department of Anatomy, Histology and Forensic Medicine, Università degli Studi di Firenze, Viale Morgagni 85, Italy. The study protocol was in accordance with the Declaration of Helsinki for Human Research.

The subjects trained on average three times a week (90-120 min/sessions) and played one match per week. Collection of hair for genotyping, measurement of anthropometry, body composition, and athletic performance reported in this study were measured once, about one month after the beginning of the regular season, *i.e.* in the month of October. All subjects had been training

and playing in the previous regular season. Measurements were performed at 9 am, about one h after a typical light Italian breakfast mainly composed of carbohydrates (one glass of fruit juice, bread and marmalade, or bread and chocolate spread, following the example of the National Football Team). All measurements were performed in a temperature-controlled room with temperature set at 24 °C.

Data for sedentary control populations were obtained from current literature.

Procedures

Anthropometric measurement, body composition assessment and physical performances evaluation

Height, weight and date of birth were recorded. Body composition was assessed by single frequency (50 kHz) bioelectrical impedance analysis with the standard hand-foot electrode placement (13) (BIA 101 Anniversary Akern Srl, Firenze-Italy). Results of the conventional bioelectrical impedance analysis such as FM, FFM, and BCM were obtained by the algorithms of the software Bodygram PRO (Akern Srl, Firenze-Italy). The R and *Xc* values were normalized by the standing height (H), then plotted on the R-*Xc* graph and evaluated with bioelectrical impedance vector analysis (14, 15, 19). The PA was calculated by the mathematical formula arctan (*Xc*/R).

Athletic performance was studied by standard functional performance field tests (7, 8, 9, 20, 21, 22) *i.e.* the SJ and the CMJ, evaluated by the "Bosco System" force platform, Globus Italia Srl, Treviso, Italy), and 10 and 20 meter sprint time (recorded by TAC photocells; TT Sport, Srl, *Repubblica di San Marino*). Furthermore, a specific test for soccer players with a 2 kg medicine ball throw was used to evaluate the upper limbs explosive strength. All these tests were performed in the gym of the Training Methodology and Applied Biomechanics' Laboratory at about 10 am.

VDR and ACE genotyping

DNA was obtained from the hair of each subject using a QIAamp® DNA Tissue Mini Kit (QIAGEN S.p.A., Milano, Italy) and amplified by a polymerase chain reaction (PCR). Amplification was performed in a final volume of 50 μL containing 200 ng of genomic DNA, 240 ng of each primer (Genenco M-medical S.r.l., Milano, Italy), and 25 μL of HotStarTaq Master Mix Kit (QIAGEN S.p.a., Milano, Italy), using standard conditions on a Mini Cycler (Mj Research Inc. Genenco Mmedical S.r.l., Milano, Italy). For detection of the polymorphic *Fok*I restriction enzyme site, two primers were used: downstream primer 5'-AGC TGG CCC TGG CAC TGA CTC TGC TCT, and upstream primer 5'-ATG GAA ACA CCT TGC TTC TTC TCC CTC. Samples were then digested at 55°C for 3 h with the appropriate restriction enzyme (FokI; Fermentas M-medical S.r.l., Milano, Italy). The digested samples were then analyzed on 2% agarose gels (Shelton Scientific Corporation, Peosta, IA, USA) after ethidium bromide staining. Absence or presence of the *Fok*I restriction site were denominated "*F*" and "*f*" respectively.

For ACE polymorphism analysis, each genotype was identified by the amplification of a sequence in the intron 16, using appropriate primers (2). Since the D allele in heterozygous subjects is preferentially amplified, each DD genotype was confirmed by a second independent PCR with a primer pair that amplified the insertion-specific sequence (2). Primers and restriction enzyme were purchased from Fermentas M-medical Srl., Milano, Italy. The DNA fragments were analyzed, on 2% agarose gels (Shelton Scientific Corporation, Peosta, IA, USA).

Statistical analyses

The differences between observed and expected frequency genotype distributions were evaluated by the χ^2 test. The χ^2 test was used to test association of categorical data. Differences in frequency genotype distributions between athletes and control population were considered statistically significant when p was ≤ 0.05.

Comparison of value distribution of *Xc*, PA, BCM/FFM, SJ, and CMJ in each ACE and VDR genotype was analyzed by ANOVA *F*-test (performed by SAS 9.1 software) since more than two groups were compared at the same time. The graphic representation of the value distribution of each parameter according to each genotype was performed by box plot charts.

In the box plot charts, the box bounds the first and third quartiles (inter-quartile range, corresponding to the box width), encompasses 50% of the data and includes the median (line within the box). Dispersion of the data above and below this range is marked by 'whiskers' that extend to the most extreme values within a "fence" at 1.5 times the inter-quartile range The "outliers" observations, indicated as rings, lie more than 1.5 times the inter-quartile range from the first and third quartile. Differences in value distribution were considered statistically significant when p was ≤ 0.05.

Means value $\pm$ SD (standard deviation) was calculated for each parameter in each genotype.

RESULTS

Genotype ACE I/D frequency distribution in young soccer players (Table 1) did not significantly vary from the genotype frequency distribution observed in the sedentary population taken as control (23). In contrast, VDR *Fok*I polymorphism distribution was significantly different in young soccer players in comparison to that observed in the sedentary control population (24). The frequency of the homozygous *ff* genotype was considerably higher in the young soccer players (0.14) as opposed to those in the control group (0.07) (Table 2). These results can be interpreted as if those subjects harbouring the homozygous *ff* genotype were more predisposed to successful soccer playing and they are consistent with the data reported in the literature demonstrating that quadriceps isometric and concentric strength are higher in *ff* homozygotes (25).

Analyzing values of body composition, we observed that reactance (*Xc*) and PA values were differently distributed in the three ACE genotypes (DD, ID and II) with the *Xc* and PA mean value higher in athletes harbouring the D allele. Mean values of *Xc* were: 61 $\pm$ 5.1 Ω in subjects with the DD genotype, 63 $\pm$ 4.7 Ω in subjects with the ID genotypes and 53 $\pm$ 4.1 Ω in subjects with the II genotype (Figure 1). Mean values for PA were: 6.8 $\pm$ 0.6° in subjects with the DD genotype, 6.7 $\pm$ 0.6° in subjects with the ID genotype and 6.2 $\pm$ 0.3° in subjects with the II genotype (Figure 2). Differences for value distribution of *Xc* and PA were statistically significant with $p = 0.04$.
No significant differences between ACE genotypes were found in the mean values of the other anthropometric and bioelectrical impedance analysis parameters studied (not shown). These results appear to demonstrate that, among anthropometric and bioelectrical impedance values, only *Xc* and PA were associated with the different ACE genotypes, and in particular with the presence of the D allele; such a selective association strongly suggests that this is association is not a mere chance but has a physiological significance.

Concerning the studied VDR genotypes (*FF*, *Ff* and *ff*), we observed association of genotypes with *Xc*, PA and BCM/FFM ratio as shown in the box plot charts in Figure 3, 4, and 5.

Considering the mean values of these three parameters, we observed that subjects with the *FF* genotype exhibited mean values of *Xc*, PA and BCM/FFM higher than those observed in subjects with *Ff* and *ff* genotypes. Specifically, mean value ± SD for *Xc* was 65 ± 4.9 Ω in subjects with the *FF* genotype; 57 ± 4.7 Ω in subjects with the heterozygous *Ff* genotype, and 61 ± 5.2 Ω in subjects with the *ff* genotype. The mean value ± SD of PA was 7.1 ± 0.4° in subjects with the FF, 6.4 ± 0.6° in subjects with the *Ff* genotype, and 6.9 ± 0.5° in subjects with the *ff* genotype. The mean value of BCM/FFM ± SD was 0.59 ± 2 in subjects with *FF*, 0,55 ± 2 in subjects with *Ff* genotype, and 0.58 ± 1 in subjects with the *ff* genotype. Differences in value distribution were statistically significant with p = 0.02 (for *Xc*), p = 0.03 (for PA) and p = 0.03 (for BCM/FFM).

Next, we studied the association between genotypes and athletic performance. Subjects with the ID genotype displayed a significantly different distribution of SJ values in comparison with subjects with DD and II genotypes with p = 0.02. SJ mean values ± SD were higher in athletes with the ID genotype (37.4 ± 4.0 cm) than in subjects with the DD (33.1 ± 3.9 cm) and II genotypes (30.4 ± 4.6 cm) (Figure 6).

Distributions of CMJ values were significantly different in the ACE I/D genotypes with p =0.04 (Figure 7). Also in this case, the mean values ± SD of CMJ were higher in subjects with the ID genotype (38.8 ± 3.6 cm) than in subjects with the DD (35.9 ± 4.1cm) and II genotypes (34.7 ± 1.9 cm). Taken together these results seem to indicate that the heterozygous ID genotype is associated with the best performances in SJ and CMJ.

No significant difference was observed in athletic performances among the athletes with different VDR genotypes (data not shown). Also, no significant difference was observed in performances related to 10 and 20 meter sprint times or medicine ball throw.

DISCUSSION

This is the first study evaluating the distribution of ACE and VDR *Fok*I polymorphisms in young soccer players and their association with athletic performances, bioelectrical impedance analysis parameters and anthropometric characteristics. We found a significant difference in the distribution of VDR *Fok*I polymorphisms between our group of medium-high level soccer players and a sedentary control population. From a gene analysis perspective, these results can be interpreted considering the known association between VDR polymorphisms and quadriceps isometric and concentric strength (25), *i.e*. a trait of fundamental importance in playing soccer. In other words, it is feasible that untrained children having the genetic advantage of stronger quadriceps tend to perform better in their early attempts and are thus encouraged to pursue their passion. Because of this, the *ff* homozygous genotype (*i.e.* the one associated with quadriceps strength) is overrepresented in the population considered in this study. It also appears, however, that the initial advantage provided by the *f* allele is overcome by intense training; in fact in the well-trained population that we studied, no difference in athletic performance was observed between athletes harbouring the three different VDR genotypes. From a practical point of view, these results can be used by coaches to identify those young athletes harbouring the less favorite VDR genotypes (*i.e. Ff* and *FF*) in order to train them adequately with the goal of increasing their strength, thus compensating the relative genetic disadvantage.

Concerning the role of ACE polymorphisms, this study demonstrates that the heterozygous genotype (ID) was associated with certain athletic performances, such as SJ and CMJ, but not with others. Since soccer is a stop and go sport involving a wide spectrum of exercise tasks at various intensities, this association could be exploited to identify those athletes that could better perform in roles involving jumping or tackling.

As far as the relationships between *Xc* (and PA), anthropometric measures, genotypes and performances are concerned, our study demonstrates that in a well-trained athlete population *Xc* and

PA as well as anthropometric values were not correlated with athletic performance. In fact, we observed significant differences in *Xc* and PA values and in the BCM/FFM ratio in athletes harbouring the three VDR genotypes whereas, in the same athletes, no differences in performances could be detected. There was, however, a correlation between *Xc* and PA values, SJ and CMJ performance and the presence of the D allele in the ID and DD genotypes as if the D allele played a dominant role over the I allele. Taken together these results at first may appear at odds with some data reported in the literature highlighting the association between physical performance and PA; in fact PA was reported to be correlated with values of maximum strength with isometric grip (26), and it was higher in trained subjects compared to untrained controls (27, 28). PA also increased with age in children (29) and decreased with age in adults and elderly (17, 30). However, it should be noticed that in the studies reported above, PA values were compared in different populations (*e.g.* trained *vs* untrained). Thus, our data can be interpreted as if training compensated for differences in PA and trained athletes with different PA values nevertheless did not show differences in physical performances.

PRACTICAL APPLICATIONS

It is well assessed that many sport- and exercise-related traits are inherited; nevertheless much of exercise physiology research has been focussed predominantly on environmental factors. As a consequence, questions concerning the role of genetic profiles associated with sport- and exercise-related traits and the application of such knowledge, are still largely unanswered. There are different reasons that would render extremely useful identifying genetic profiles associated with athletic performances. First, they could provide information about the genetic and molecular mechanisms underlying athletic performance. Second, such information could be related to physiology and pathology and thus become useful in sport medicine as well as in general medical practice. Third, the knowledge of the variations (polymorphisms) in DNA sequence associated with

athletic performance may represent a tool to develop genetic tests designed at predicting the potential for performance. Individuals, their tutors and their coachers might use these tests to make decisions such as to become a professional athlete or to choose a given sport. Since most people commit to a discipline while young and require prolonged training during their growing years to become elite athletes, it is foreseeable that in the near future genetic performance tests will be used to identify the most appropriate athletic discipline for each individual and prevent minors from choosing to embark on an eventually fruitless training programme.

REFERENCES

1. Davids K, Baker J. Genes, envrinmont and sport performance: why the nature-nurture dualism is no longer relevant. *Sports Med* 37: 961-980, 2007.

2. Alvarez R, Terrados N, Ortolano R, Iglesias-Cubero G, Reguero JR, Batalla A, Cortina A, Fernández-García B, Rodríguez C, Braga S, Alvarez V, Coto E. Genetic variation in the renin-angiotensin system and athletic performance. *Eur J Appl Physiol* 82: 117-120, 2000.

3. Nakamura O, Ishii T, Ando Y, Amagai H, Oto M, Imafuji T, Tokuyama K. Potential role of vitamin D receptor gene polymorphism in determining bone phenotype in young male athletes. *J Appl Physiol* 93: 1973-1979, 2002.

4. Collins M, Xenophontos SL, Cariolou MA, Mokone GG, Hudson DE, Anastasiades L, Noakes TD. The ACE gene and endurance performance during the South African Ironman Triathlons. *Med Sci Sports Exerc* 36: 1314-1320, 2004.

5. Rabon-Stith KM, Hagberg JM, Phares DA, Kostek MC, Delmonico MJ, Roth SM, Ferrel RE, Conway JM, Ryan AS; Hurley BF. Vitamin D receptor FokI genotype influences bone mineral density response to strength training, but not aerobic training. *Exp Physiol* 90: 653-661, 2005.

6. Ruggiero M, Pacini S. Chronic kidney disease and vitamin D: how much is adequate? *Kidney Int* 76: 931-933, 2009.

7. Svensson M, Drust B. Testing soccer players. *J Sports Sci* 23(6): 601-618, 2005.

8. Wong del P, Wong SH. Physiological profile of Asian elite youth soccer players. *J Strength Cond Res* 23(5): 1383-1390, 2009.

9. Wong PL, Chamari K, Dellal A, Wisløff U. Relationship between anthropometric and physiological characteristics in youth soccer players. *J Strength Cond Res* 23(4): 1204-1210, 2009.

10. Midorikawa T, Sekiguchi O, Beekley MD, Bemben MG, Abe T. A comparison of organ-tissue level body composition between college-age male athletes and nonatletes. *Int J Sports Med* 28: 100-105, 2007.

11. Lukasky HC, Bolonchuk WW, Siders WA, Hall B. Body composition assessment of athletes using bioelectrical impedance measurements *J Sport Med Phys Fitness* 30: 434-440, 1990.

12. Guida B, Laccetti R, Gerardi C, Trio R, Perrino NR, Strazzullo P, Siani A, Farinaro E, Colantuoni A. Bioelectrical impedance analysis and age-related differences of body composition in the elderly. *Nutr Metab Cardiovasc Dis* 17(3): 175-180, 2007.

13. Barbosa-Silva MCG, Barros AJD. Bioelectrical impedance analysis in clinical practise: a new perspective on its use beyond body composition equations. *Curr Opin Clin Nutr Metab Care* 13: 311-317, 2005.

14. Piccoli A, Rossi B, Pillon L, Bucciante G. A new method for monitoring body fluid variation by bioimpedance analysis: the R*Xc* graph. *Kidney Int* 46(2): 534-539, 1994.

15. Piccoli A, Nigrelli S, Caberlotto A, Bottazzo S, Rossi B, Pillon L, Maggiore Q. Bivariate normal values of the bioelectrical impedance vector in adult and elderly populations. *Am J Clin Nutr* 61(2): 269-270, 1995.

16. Nunez C, Gallagher D, Grammes J, Baumgartner RN, Ross R, Wang Z, Thorton J, Heymsfield SB. Bioimpedance analysis: potential for measuring lower limb skeletal muscle mass. *JPEN J Parenter Enteral Nutr* 23(2): 96-103, 1999.

17. Dittmar M. Reliability and variability of bioimpedance measures in normal adults: effects of age, gender, and body mass. *Am J Phys Anthropol* 122(4): 361-370, 2003.

18. Marra M, Pasanisi F, Scalfi L, Colicchio P, Chelucci M, Contaldo F. The prediction of basal metabolic rate in young adult, severely obese patients using single-frequency bioimpedance analysis. *Acta Diabetol* 40(Suppl. 1): S139–S141, 2003.

19. Kyle UG, Bosaeus I, De Lorenzo AD, Deuremberg P, Elia M, Gómez JM, Heitmann BL, Kent-Smith L, Melchior JC, Pirlich M, Scharfetter H, Schols AM, Pichard C. Bioelectrical impedance analysis-part I: review of principles and methods. *Clin Nutr* 23: 1226-1243, 2004.

20. Bosco C, Luhtanen P, Komi PV. A simple method for measurement of mechanical power in jumping. *Eur J Appl Physiol Occup Physiol* 50(2): 273-282, 1983.

21. Caldwell BP, Peters DM. Seasonal variation in physiological fitness of a semiprofessional soccer team. *J Strength Cond Res* 23(5): 1370-1377, 2009.

22. Chelly MS, Chérif N, Amar MB, Hermassi S, Fathloun M, Bouhlel E, Tabka Z, Shephard RJ.Relationships of peak leg power, 1 maximal repetition half back squat, and leg muscle volume to 5-m sprint performance of junior soccer players. *J Strength Cond Res* 24(1): 266-271, 2010.

23. Scanavini D, Bernardi F, Castoldi E, Conconi F, Mazzoni G. Increased frequency of the homozygous II ACE genotype in italian olympic endurance athletes. *Eur J Hum Genet* 10: 576-577, 2002.

24. Naderi N, Farnood A, Habibi M, Derakhshan F, Balaii H, Motahari Z, Agah MR, Firouzi F, Rad MG; Aghaza deh R, Zojaji H, Zali MR. Association of vitamin D receptor gene polymorphisms in iranian patients with inflammatory bowel disease. *J Gastroenterol Hepatol* 23: 1816-1822, 2008.

25. Windelinckx A, De Mars G, Beunen G, Aerssens J, Delecluse C, Lefevre J, Thomis MA. Polymorphisms in the vitamin D receptor gene are associated with muscle strength in men and women. *Osteoporos Int* 18: 1235-1242, 2007.

26. Norman K, Pirlich M, Sorensen J, Christensen P, Kemps M, Schütz T, Lochs H, Kondrup J. Bioimpedance vector analysis as a measure of muscle function. *Clin Nutr* 28: 78-82, 2009.

27. Piccoli A, Pastori G, Codognotto M, Paoli A. Equivalence of information from single frequency v. bioimpedance spectroscopy in bodybuilders. *Br J Nutr* 97(1): 182-192, 2007.

28. Marra M, Caldara A, Montagnese C, De Filippo E, Pasanisi F, Contaldo F, Scalfi L Bioelectrical impedance phase angle in constitutionally lean females, ballet dancers and patients with anorexia nervosa. *Eur J Clin Nutr* 63(7): 905-908, 2009 .

29. Bonaccorsi G, Baggiani L, Bassetti A, Colombo C, Lorini C, Mantero S, Olimpi N, Santomauro F, Comodo N. Body composition assessment in a sample of eight-year-old children. *Nutrition* 25(10): 1020-1028, 2009.

30. Kyle UG, Genton L, Slosman DO, Pichard C. Fat-free and fat mass percentiles in 5225 healthy subjects aged 15 to 98 years. *Nutrition* 17: 534-541, 2001.

FIGURE LEGENDS

Figure 1. Box plot representation of the distribution of *Xc* values for each ACE I/D genotype.

Figure 2. Box plot representation of the distribution of PA values for each ACE I/D genotype.

Figure 3. Box plot representation of the distribution of *Xc* values for each VDR *Fok*I genotype.

Figure 4. Box plot representation of the distribution of PA values for each VDR *Fok*I genotype.

Figure 5. Box plot representation of the distribution of BCM/FFM values for each VDR *Fok*I genotype.

Figure 6. Box plot representation of the distribution of SJ values for each ACE I/D genotype**.**

Figure 7. Box plot representation of the distribution of CMJ values for each ACE I/D genotype**.**

Table 1. Distribution of ACE I/D genotype in young soccer players and comparison with control population.

		Genotype frequency (athletes)	**Genotype frequency (control)**	**p**
ACE	*DD*	**0.51** (64/125)	**0.44** (67/152)	0.09
	ID	**0.42** (52/125)	**0.43** (66/152)	
	II	**0.07** (9/125)	**0.13** (19/152)	

Control population: 152 healthy subjects [23].

Table 2. Distribution of VDR *Fok*I genotype in young soccer players and comparison with control population

		Genotype frequency (athletes)	Genotype frequency (control)	p
VDR	*FF*	**0.52** (64/125)	**0.54** (81/150)	0.005
	Ff	**0.34** (43/125)	**0.39** (59/150)	
	ff	**0.14** (18/125)	**0.07** (10/150)	

Control population: 150 healthy subjects [24].

Figure 1
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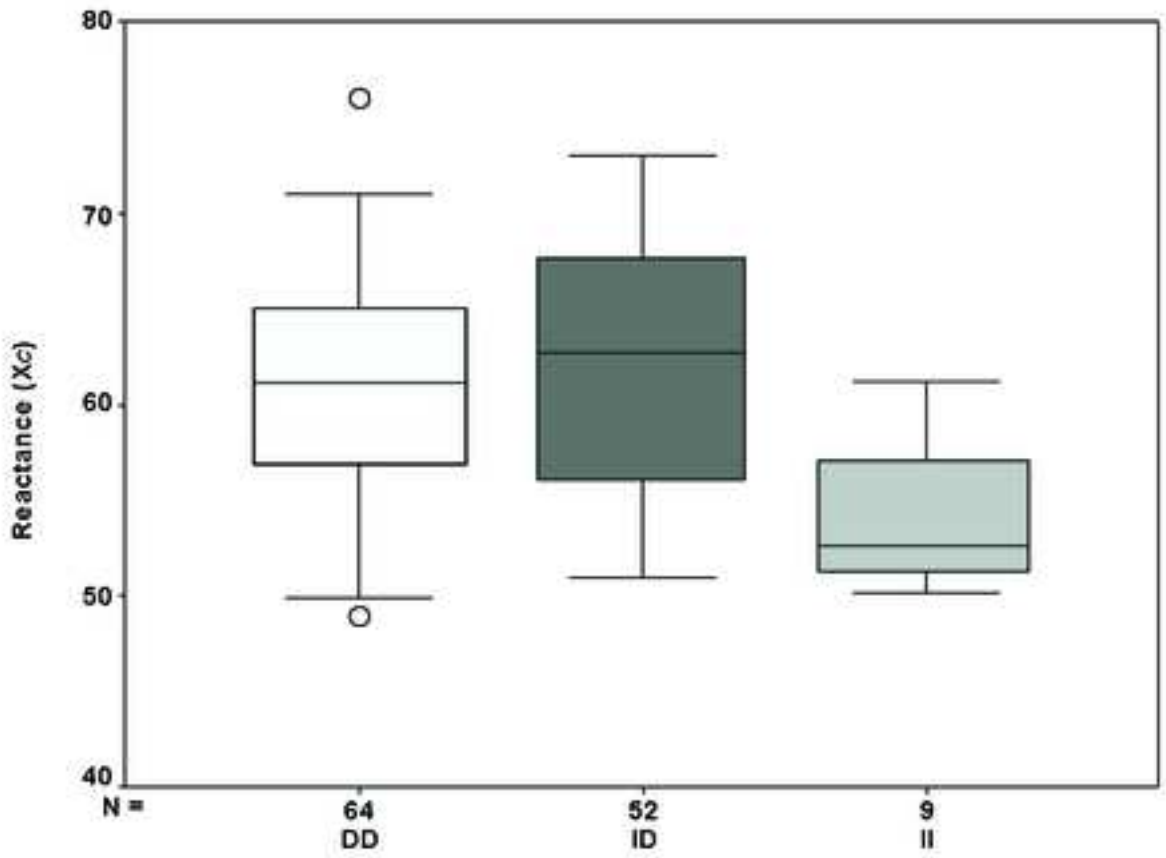
Figure 1.



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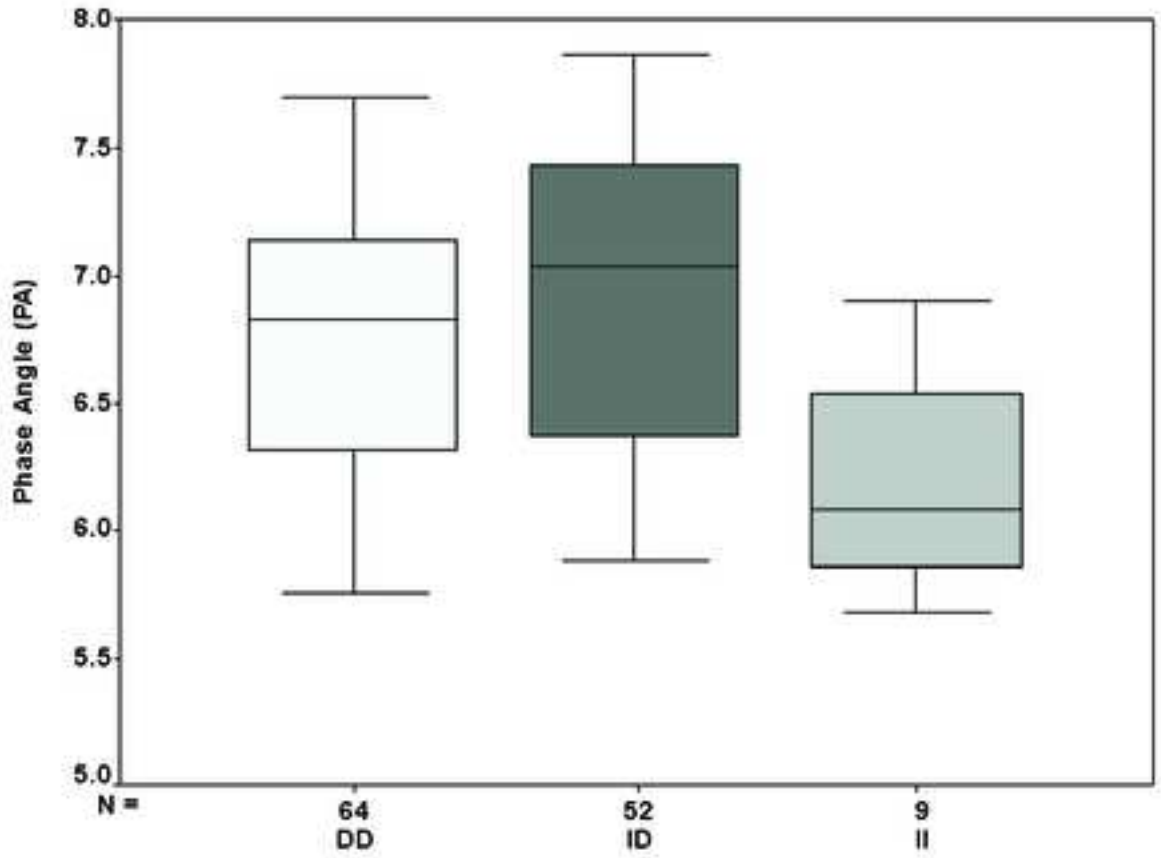

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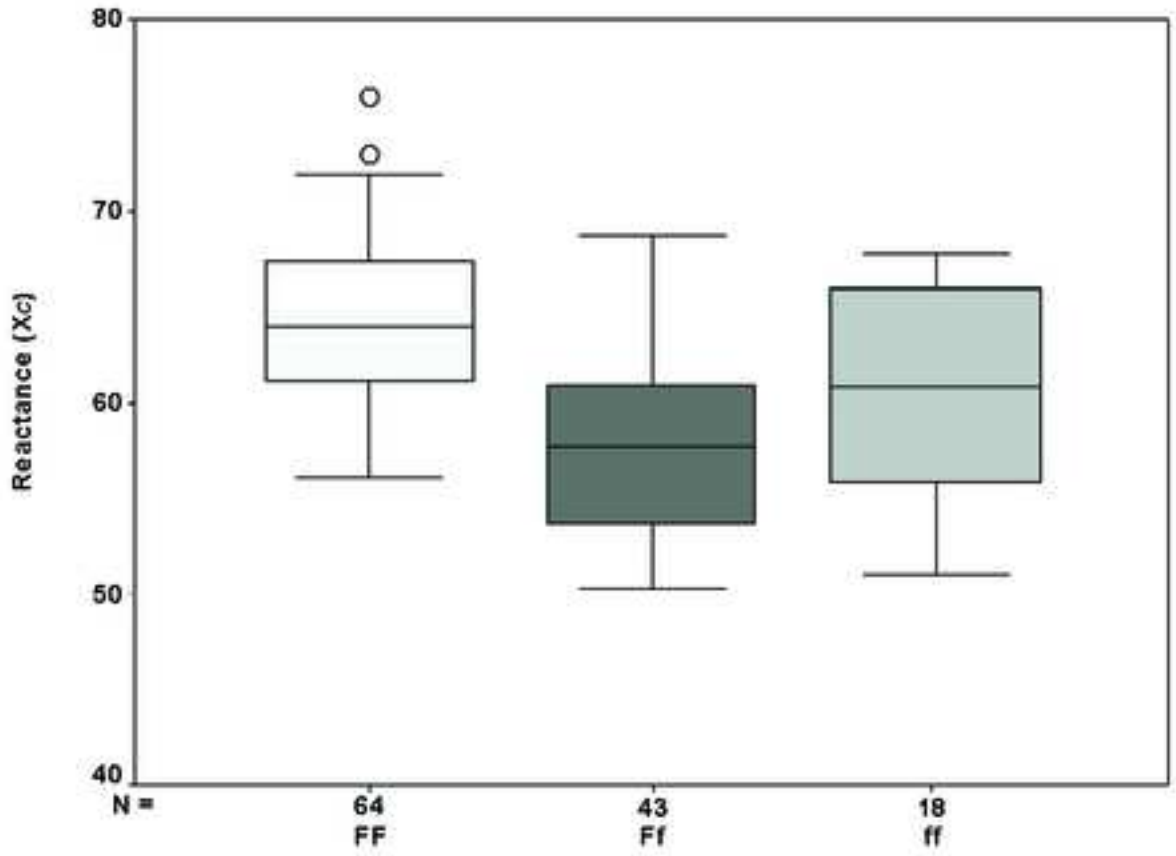

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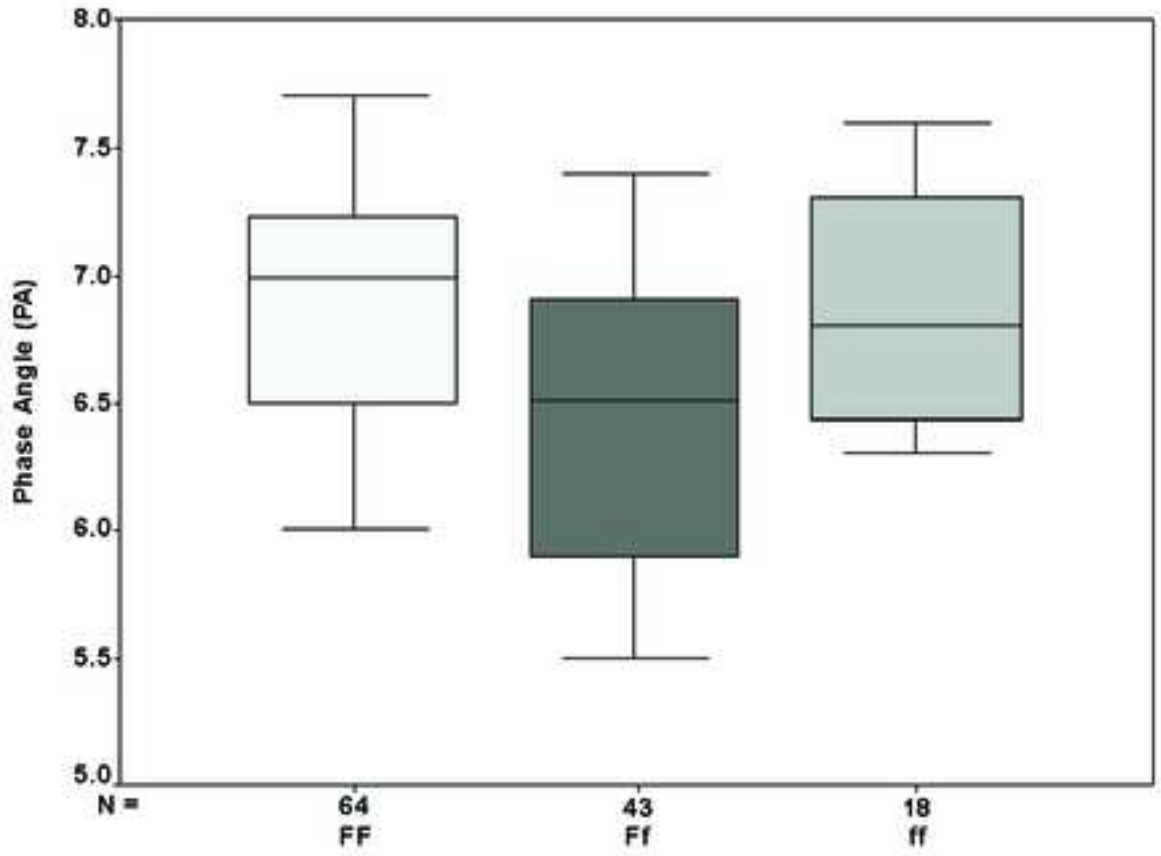

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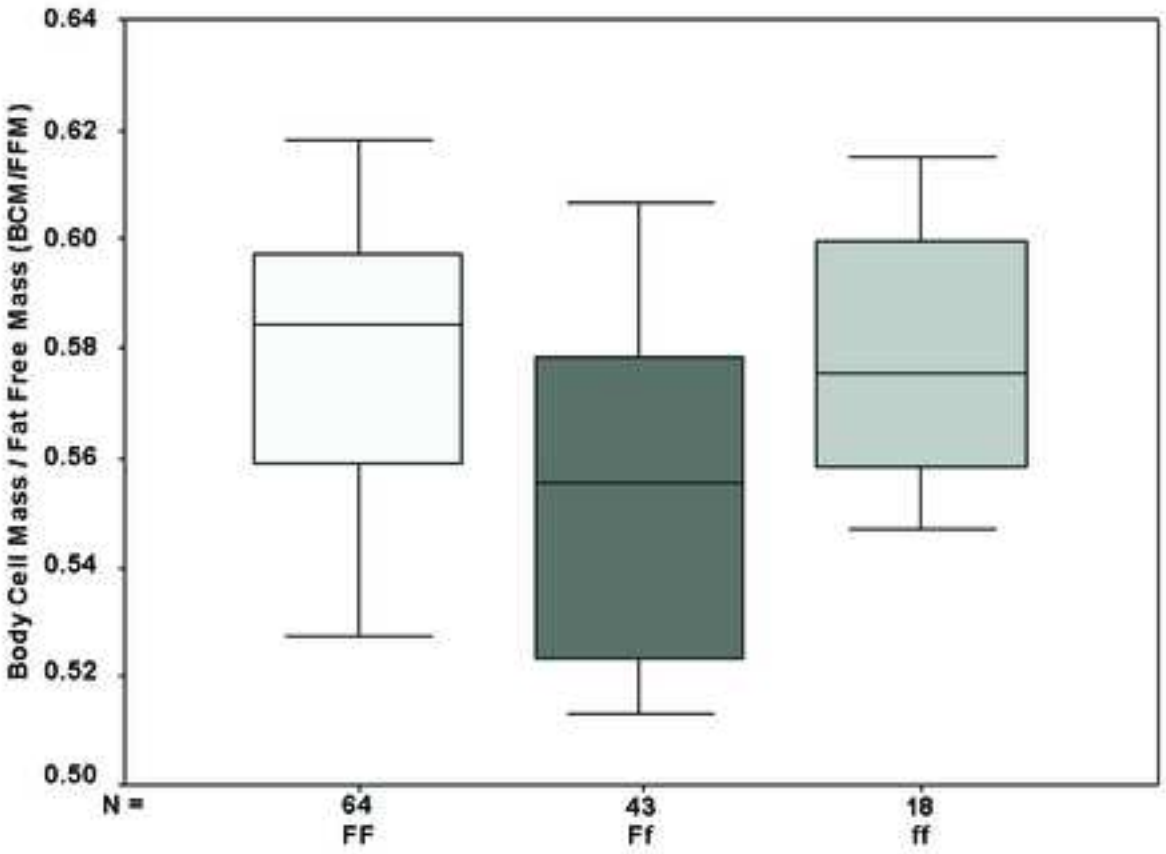

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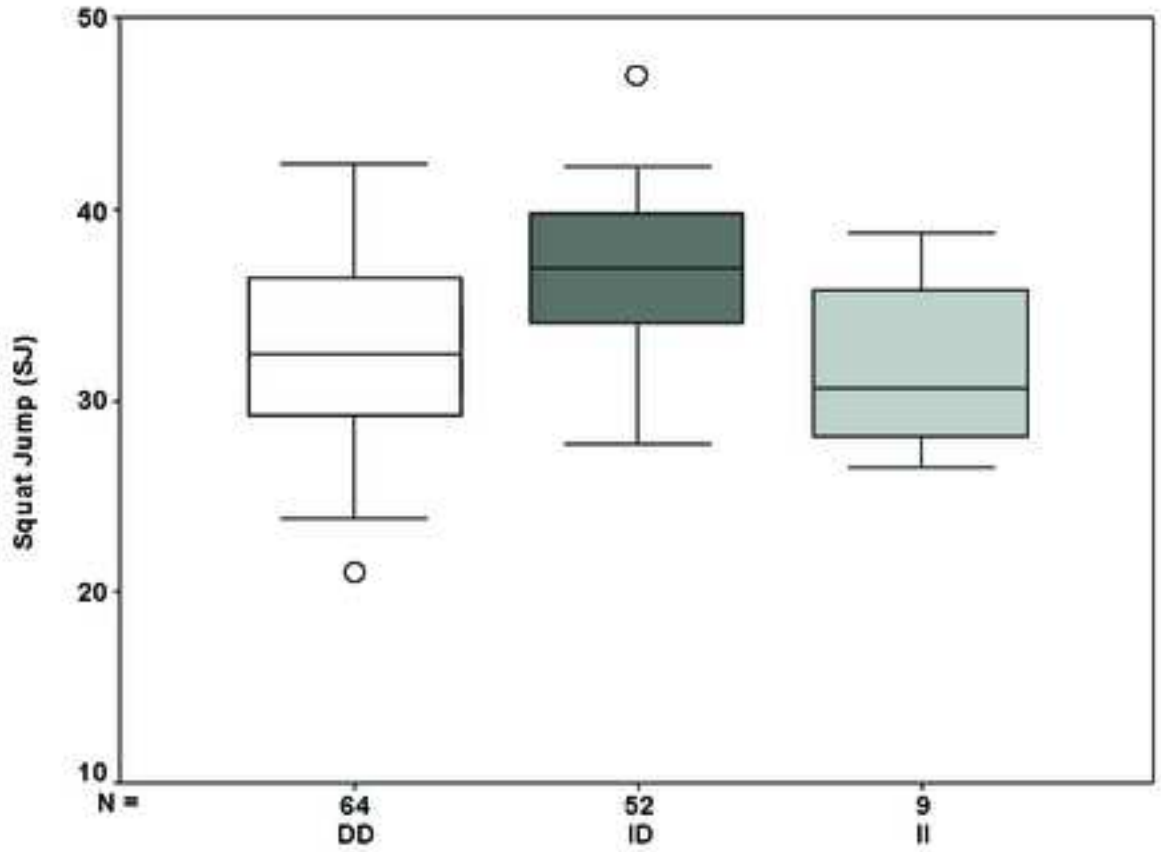

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