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Power training in young athletes: is it all in the genes?

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Abstract

Introduction. The aim of the study was to evaluate the effects of plyometric and isometric training protocol on power in 46 team sports (basketball: n = 23; volleyball: n = 23) players, also in relation to genetic background (i.e., ACE and PPARA genes polymorphisms).

Methods. The following tests were administered: squat jump (SJ), countermovement jump (CMJ), drop jump (DJ), sprint, handgrip, and agility test. Genetic analysis was based on saliva samples.

Results. The training protocol proved to be effective in improving jump performance in basketball players and volleyball players, respectively: 25-meter sprint test (p = 0.006; p = 0.008); agility test (p = 0.000; p = 0.000); SJ test (p = 0.001; p = 0.000); CMJ test (p = 0.005; p = 0.000); and DJ test (p = 0.03 only for basketball players; DJ test improvement in volleyball players was not significant), regardless of sports practice. Furthermore, data confirm that the 'D' allele of ACE and the 'C' allele of PPARA are positive alleles associated to power and strength performances.

Conclusions. The importance to train strength skills should be emphasized, above all through isometric and plyometric exercises, not neglecting the key role played by the genetic background.

Key words: PEPs, basketball, volleyball, isometric, plyometric, power skills

Introduction

Genetic architecture could become an important tool to structure personalized workouts, allowing to obtain the best performance not only in elite athletes but also in young ones, who, although in an optimal phase of their lives to stimulate and develop at best the innate abilities related to genetic predispositions, are often trained with standardized workouts. Recent studies show that more than 200 gene variants are associated to fitness-related phenotypes and consequently to sports performance. Among the performance enhancing polymorphisms (PEPs) [1, 2], peroxisome peroxide-activated receptors (PPAR) and angiotensin converting enzyme (ACE) are of particular interest. The former is involved in mitochondrial activity and in triglycerides metabolism and seem to be related to body mass index (BMI) [3, 4]. The 'G' allele of PPAR polymorphism predisposes to better endurance performance, whilst the 'C' allele to better power performance [5, 6]. The ACE enzyme has different functions, such as to catalyse the conversion of angiotensin I into angiotensin II (a potent vasoconstrictor) in tissues; to degrade, making it inactive, bradykinin; and to promote cardiac cells growth. It has two alleles: the 'I' allele predisposes to better endurance performance (in fact, it is linked to elite soccer player status) [7, 8], whilst the 'D' allele predisposes to better power performance [9, 10]. The roles of ACE and PPAR alpha (PPARA) seem to be fundamental in team sports, such as volleyball and basketball. Volleyball is classified as aerobic-anaerobic activity characterized by a high level of strength and neuromuscular coordination during short time actions involving anaerobic alactacid metabolism [11].

Also basketball is mainly considered an aerobic-anaerobic team sport [12], given the use of motor patterns such as jumping, sprinting, acceleration/deceleration, and changes of direction [13, 14]. Studies in the genetic field suggest the correlation between the development of the aforementioned physical qualities and specific (i.e., ACE and PPARA) gene polymorphisms [5].

Coaches have focused their attention on these aspects, understanding how improvement of explosive strength (i.e., power) may be the key to jump and sprint in basketball performance. Among the different protocols proposed, the effectiveness of isometric and plyometric exercises has been reported to be the most efficient in team sports [15, 16]. Therefore, the aim of this study was to verify the effectiveness of isometric and plyometric training protocol in basketball and volleyball players, also in relation to their genetic profile.

Subjects and methods

The total of 46 young athletes (23 basketball players and 23 volleyball players) with at least 3 years of previous practice participated in the study, approved by the local institutional review board. In each group (B – basketball; V – volleyball), 12 athletes were randomly assigned to a 6-week experimental training protocol (training group [TG]), implemented twice a week during their regular weekly training, whereas the remaining 11 athletes engaged in their regular weekly training sessions (control group [CG]). The average age was 11.6 ± 0.8 years in TGB, 11 ± 0.7 years in CGB, 13 ± 2 years in TGV, and 11 ± 1.3 years in CGV.

Anthropometric measurements

Weight and height were recorded in all athletes. Height was measured in meters (m) with the use of a wall stadiometer,

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whereas weight was determined in kilograms (kg) with digital scales. BMI was then obtained from the formula: weight (kg)/height $(m)^2$. The anthropometric measurements are shown in Tables 1 and 2.

Performance evaluations

The interaction between force of contraction and speed of movement (i.e., power) appears to be effective in representing the sport-specific fundamental movements of team sport play. Jump and sprint tests are frequently used by coaches, being easy to set and simple to interpret [14, 17, 18]. Furthermore, handgrip strength is of particular interest because of the continuous use of hands in basketball and volleyball. Thus, squat jump (SJ), countermovement jump (CMJ), and drop jump (DJ) tests according to Bosco [19], 25-meter sprint or sprint test (where the subjects run from start line to stop line for 25-m distance), and handgrip test were administered, following the protocol presented by Latorre Román et al. [13].

Agility in space-time translocation, a fundamental parameter in both sports, was evaluated with the use of agility test by Semenick [20]; particularly, the standard height applied for DJ was 40 cm.

Experimental training

After a warm-up consisting of a 5-minute low-intensity run followed by general and specific sports exercises, the experimental training consisted of a 10–20-minute combined protocol of one isometric exercise and two plyometric exercises, administered by the same certified trainer (TG). The exercises were as follows:

– Exercise 1 (E_1): half isometric squat, knee flexed at 90°.
– Exercise 2 (E_2): vertical jump, from the sitting position.
– Exercise 3 (E_3): vertical-forward jump followed by an immediate jump, starting from half squat position, knee flexed to 90°.

E_1 had an initial duration of 40–60 seconds, while in E_2 and E_3, the volume increased from 50 to 100 jumps; the time and volume were increased every 2 weeks (Table 3).

Genotyping

For genetic analysis, a saliva sample (that is less invasive and simpler alternative to blood sampling) was taken from each subject with the use of a 10-ml sterile tube. Each sample was stored in a freezer at –20°C before use, and DNA was extracted with a specific kit (Norgen Biotek Corporation). ACE Alu I/D and PPARA intron 7 G/C gene polymorphisms were genotyped from all 46 athletes. The genetic analysis was performed with a polymerase chain reaction (PCR) followed by enzymatic digestion if necessary, with specific restriction enzymes. The amplification protocol for all polymorphisms provided denaturation at 94°C for 5 minutes; 35 denaturation cycles at 94°C for 1 minute; variable annealing according to restriction enzymes from 50°C to 66°C for 1 minute, and an extension to 72°C for 1 minute; a final cycle at 72°C for 10 minutes (Table 4).

Table 1. Anthropometric measurements in basketball players

Group (n)	Age (years)	Height (m)	Weight (kg)	BMI (kg/m²)
TGB (12)	12 ± 1	1.53 ± 7	50.3 ± 12.5	21.3 ± 3.9
CGB (11)	11 ± 1.3	1.57 ± 7	47.1 ± 5	18.9 ± 1.4

TGB – training group basketball, CGB – control group basketball

Table 2. Anthropometric measurements in volleyball players

Group (n)	Age (years)	Height (m)	Weight (kg)	BM I (kg/m²)
TGV (12)	11.6 ± 0.8	1.56 ± 7.3	48.5 ± 6.7	20 ± 2.6
CGV (11)	11 ± 0.7	1.51 ± 7.6	44.1 ± 6.07	19.31 ± 1.6

TGV – training group volleyball, CGV – control group volleyball

Table 3. Experimental training protocol

Weeks	Exercises	Series/Repetitions × Recovery (s)	Volume (min) – jumps number
1–2	E_1 (40 s) + E_2: 3 × 10 + E_3: 2 × 10	5/10 × 90	10 – 50
3–4	E_1 (50 s) + E_2: 4 × 10 + E_3: 3 × 10	7/10 × 90	15 – 70
5–6	E_1 (60 s) + E_2: 5 × 10 + E_3: 5 × 10	10/10 × 90	22 – 100

E – exercise

Table 4. Description of the genotyping methods for each analysed polymorphism

Gene	Primers	Annealing	Enzyme restriction	Genotypes
ACE	F:5'GCCCTGCAGGTGTCTGCAGCATGT3' R:5'GGATGGCTCTCCCCGCCTTGTCTC3'	66°C	–	I/I I/D D/D
PPARα	F:5'ACAATCACTCCTTAAATATGGTGG 3' R:5'AAGTAGGGACAGACAGGACCAGTA 3'	59°C	Taq I	G/G G/C C/C

Statistic analysis

The data of the anthropometric measurements and the subjects' age are described with averages and standard deviations. The performance improvement results were evaluated in both groups with the *t*-test, that is a statistic parametric test using the IBM SPSS Statistics software. The same test was applied to analyse the results based on the genetic background considering the ACE and PPARA polymorphism. Values of $p < 0.05$ were considered statistically significant.

Ethical approval

The research related to human use has been complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the authors' institutional review board or an equivalent committee.

Informed consent

Informed consent has been obtained from the parents of all individuals included in this study.

Results

Physical performance

For basketball players, TG showed a statistically significant difference in all tests performed (sprint, agility, SJ, CMJ, DJ tests), as shown in Table 5, whilst CG presented a statistically significant variation only in the agility test ($p = 0.008$).

Among volleyball players, TG showed a statistically significant variation in all tests performed except the DJ test, as shown in Table 6. CG presented a statistically significant variation only in the CMJ test ($p = 0.04$).

Significant improvements have been observed for jump tests in the volleyball group (SJ: $p = 0.00004$; CMJ: $p = 0.0001$) and for sprint and agility tests in the basketball group (sprint test: $p = 0.000$; agility test: $p = 0.000$) after the training period.

Genetic analysis: ACE polymorphism

The results of the genotyping in basketball players proved a genotypic frequency of ACE gene polymorphism of 15.38% for II, 46.16% for ID, and 38.46% for DD in TG – and 10% for II, 50% for ID, and 40% for DD in CG.

For volleyball players, the genetic analysis of the same polymorphism showed a genotypic distribution of 0% for II, 66.67% for ID, and 33.33% for DD in TG, whereas in CG it was 0% for II, 63.64% for ID, and 36.36% for DD.

On dividing the entire sample of 46 subjects in accordance with the genotype in the ACE gene, we found statistically significant improvements between pre- and post-test results, particularly in SJ (especially for the DD genotype: $p = 0.02$; and ID genotype: $p = 0.00$), CMJ (DD genotype: $p = 0.00$; ID genotype: $p = 0.04$), and agility (DD genotype: $p = 0.00$; ID genotype: $p = 0.00$; II genotype: $p = 0.04$).

As for the handgrip test, a statistically significant difference emerged between the right and left hand, with the right hand value greater than the left, especially in subjects with the DD and ID genotype ($p = 0.00$; $p = 0.00$). With reference to the sprint test, only subjects with the ID genotype presented a significant improvement between pre- and post-test results ($p = 0.00$) (Table 7).

Genetic analysis: PPARA polymorphism

In the basketball players' group, the genotype distribution for PPARA polymorphism was 61.54% for CC, 23.08% for CG, and 15.38% for GG in TG – and 70% for CC, 30% for CG, and 0% for GG in CG. In volleyball players, the genotype distribution was 33.30% for CC, 66.70% for CG, and 0% for GG in TG – and 63.63% for CC, 27.29% for CG, and 9.08% for GG in CG.

For the correlation of the PPARA gene polymorphism and sports performance, there was a significant improvement in the following tests only in the subjects with the CC or CG genotype: SJ test ($p = 0.00$; $p = 0.00$), CMJ test ($p = 0.01$; $p = 0.00$), and agility test ($p = 0.00$; $p = 0.00$).

Table 5. Physical performance tests for basketball players

Test	Pre-test TGB	Post-test TGB	*p*-value	Pre-test CGB	Post-test CGB	*p*-value
Sprint test (s)	5.38 ± 0.4	5.05 ± 0.4	0.006*	5.16 ± 0.4	5.20 ± 0.4	0.56
Agility test (s)	14.16 ± 0.7	12.61 ± 0.7	0.000*	13.92 ± 0.7	13.52 ± 0.8	0.008*
SJ (cm)	26.54 ± 7.2	30.62 ± 6.3	0.001*	26.10 ± 6.2	25.40 ± 5.6	0.43
CMJ (cm)	29.31 ± 5.5	31.62 ± 5.7	0.005*	27.60 ± 5.9	26.20 ± 6.2	0.009*
DJ (cm)	26.08 ± 6.5	27.54 ± 6.2	0.03*	24.90 ± 6.0	21.90 ± 5.1	0.000*

SJ – squat jump, CMJ – countermovement jump, DJ – drop jump, TGB – training group basketball, CGB – control group basketball
* Statistically significant values

Table 6. Physical performance tests for volleyball players

Test	Pre-test TGV	Post-test TGV	*p*-value	Pre-test CGV	Post-test CGV	*p*-value
Sprint test (s)	5.33 ± 0.3	5.21 ± 0.3	0.008*	5.38 ± 0.3	5.24 ± 0.4	0.08
Agility test (s)	13.03 ± 0.7	12.16 ± 0.5	0.000*	13.33 ± 1	12.98 ± 0.6	0.09
SJ test (cm)	28.16 ± 5.1	31.83 ± 5.6	0.000*	24.45 ± 2.7	26.18 ± 2.4	0.08
CMJ test (cm)	29.5 ± 6.8	34.08 ± 6.3	0.000*	26.36 ± 4.5	29.54 ± 4	0.04*
DJ test (cm)	27.83 ± 8	30.66 ± 7.3	0.08	24.54 ± 4.7	24.81 ± 3.7	0.8

SJ – squat jump, CMJ – countermovement jump, DJ – drop jump, TGV – training group volleyball, CGV – control group volleyball
* Statistically significant values

Table 7. Genetic background analysis correlated to the performance in the whole group for ACE polymorphism

ACE	SJ pre-test (cm)	SJ post-test (cm)	CMJ pre-test (cm)	CMJ post-test (cm)	DJ pre-test (cm)	DJ post-test (cm)	Sprint pre-test (s)	Sprint post-test (s)	Agility pre-test (s)	Agility post-test (s)	Handgrip right	Handgrip left
DD *p*-value	26.47 0.02*	28.35	27.71 0.00*	30.76	26.18 0.39	25.41	5.31 0.22	5.22	13.75 0.00*	13.00	15.75 0.00*	14.76
ID *p*-value	26.70 0.00*	27.91	28.74 0.04*	27.22	25.50 0.12	15.68	5.12 0.00*	5.04	12.64 0.00*	13.83	15.00 0.00*	16.94
II *p*-value	25.67 0.19	29.33	26.33 0.27	29.00	26.00 0.63	27.33	5.35 0.10	5.14	14.15 0.04*	12.80	16.13 0.23	15.23

ACE – angiotensin converting enzyme, SJ – squat jump, CMJ – countermovement jump, DJ – drop jump, DD, ID, II – genotypes
* Statistically significant values

Table 8. Genetic background analysis correlated to the performance in the whole group for PPARA polymorphism

PPARA	SJ pre-test (cm)	SJ post-test (cm)	CMJ pre-test (cm)	CMJ post-test (cm)	DJ pre-test (cm)	DJ post-test (cm)	Sprint pre-test (s)	Sprint post-test (s)	Agility pre-test (s)	Agility post-test (s)	Handgrip right	Handgrip left
CC *p*-value	25.76 0.00*	27.94	28.15 0.01*	30.33	25.55 0.96	25.52	5.36 0.00*	5.16	13.59 0.00*	12.86	15.80 0.00*	14.72
CG *p*-value	26.47 0.00*	29.12	27.65 0.00*	30.88	26.06 0.29	27.41	5.34 0.32	5.30	13.50 0.00*	12.71	15.87 0.00*	15.21
GG *p*-value	27.00 0.42	29.33	28.67 0.34	31.00	26.33 0.46	27.67	5.04 0.69	4.89	13.96 0.12	12.71	16.37 0.24	15.13

PPARA – peroxisome peroxide-activated receptors alpha, SJ – squat jump, CMJ – countermovement jump, DJ – drop jump, CC, CG, GG – genotypes
* Statistically significant values

As for the handgrip test, a statistically significant difference was found between the right and left side, with right greater than the left, in subjects with the CC and CG genotype (p = 0.00; p = 0.00, respectively). In the sprint test, only participants with the CC genotype presented a significant improvement between the pre- and post-test results (p = 0.00) (Table 8).

Discussion

In the study, we analysed the effects of the experimental training protocol on explosive strength to improve the abilities required in basketball and volleyball such as jump, sprint, and agility. The results obtained in all performed tests demonstrated that, despite the short period of investigation, there was an improvement in most of the sports performance skills. Above all, the improvements were mainly visible in jump tests in the case of the volleyball group, and in sprint and agility tests in the basketball group.

The finding highlighted the effects of a 6-week plyometric training program on explosive strength and acceleration capacity. The results remain in line with the literature [21], showing how genetic background can influence the response to a specific training protocol; particularly, the athletes with the D allele of the ACE gene and the C allele of the PPARA gene displayed an improvement greater than other subjects (especially those with the II genotype for ACE and GG genotype for PPARA). The improvement achieved was especially prominent on explosive strength (in SJ, CMJ, and agility tests) and acceleration.

Conclusions

It is worth to emphasize the importance to train strength skills, over all through isometric and plyometric exercises, not neglecting the key role played by the genetic background, also in early age. This could be useful to identify individual strengths training protocols and plan specific workout aimed at improving sports performance in young athletes.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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