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The impact of sport-discipline and sex on physical fitness and bone markers in athletes

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Submission Style: Original Investigation

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Purpose: This study was performed to determine the impact of sex and sport-discipline on physical fitness and bone markers in young sub-elite track and field athletes.

Methods: One hundred and forty-four track and field sub-elite athletes (78 males aged 17.8 ± 1.6 years; 66 females aged 17.2 ± 1.9 years) volunteered to participate in this study and were categorized according to their disciplines in endurance (EG: n=67) or power athletes (PG: n=77).

Results: A significant main effect of sex was observed for C-telopeptide type I collagen (CTX) ($F=11.37$; $p<0.001$; $\eta^2=0.10$, moderate), for osteocalcin (OC) ($F=8.58$; $p<0.004$; $\eta^2=0.09$, moderate) and for N-terminal propeptide of procollagen type I (PINP) ($F=7.96$; $p<0.05$; $\eta^2=0.07$, moderate). The average CTX, OC and PINP levels were significantly higher in males compared with females ($0.05<p<0.001$; $\eta^2=0.07$ to 0.10 , moderate). In addition, a significant main effect of sport-discipline was observed only for PINP values ($F=10.16$; $p<0.002$; $\eta^2=0.09$, moderate) with EG showing higher levels than PG. For jumping and sprinting tests, the PG performed better than the EG. For the endurance test, EG had better performance than OG.

Conclusion: Endurance and power exercise practices can increase bone formation markers (PINP, OC), but only anaerobic training (PG group) appears to positively impact on male track and field athletes.

Key words: Gender difference; aerobic; anaerobic; physical parameters; bone markers.

INTRODUCTION

Bone deposition governs bone resorption throughout childhood and adolescence [1]. Accordingly, growth and maturation are critical for developing maximal bone mass [1]. Furthermore, high peak bone mass in youth is positively associated with bone fragility later in life [2, 3]. Hence, childhood and adolescence represent important developmental stages to maximize bone mass and strength [1]. Therefore, bone mass is known for its well-established role as connective tissue that provides mobility for the body as well as supporting and protecting vital organs [4]. These functions are recognized by the three main cell types in the skeleton: osteoblasts, osteoclasts, and osteocytes [5].

Consequently, bone tissue is highly sensitive to mechanical stress [5]. Indeed, bone unloading and loading are strictly involved in the differentiation and formation of osteoclasts and osteoblasts and their respective roles in bone resorption and formation [3, 4, 6].

Under normal conditions, bone resorption and bone formation are coupled to maintain the integrity of calcium homeostasis and maintain the integrity of the skeleton [6, 7]. Bone remodeling is orchestrated by local micro-environmental factors, cytokines, growth factors and systemic hormones (e.g., parathyroid hormone, vitamin D, calcitonin, estrogens etc.) in a complex network of interactions [5, 8].

Indeed, bone-remodeling markers can be classified into bone formation markers and bone resorption markers; thus, the variation of these markers reflects the actual situation of the bone tissue [8]. Bone biochemical markers, as serum C-telopeptide type I collagen (CTX) and serum N-terminal propeptide of procollagen type I (P1NP), reflecting the cellular activities of bone formation and resorption, are useful, both to monitor the acute exercise effects on bone remodeling and to investigate the mechanisms of exercise-induced changes in bone mass that occur during growth (in children) and aging (in seniors) [2, 3].

Certainly, physical exercise has been shown to have a substantial effect on bone turnover in older men [9], women [10], and young boys [2]. Impact loading, which is inherent in various sports (e.g., track and field), plays an imperative role in skeletal growth and shaping [11]. Preceding investigations of children and adolescents have revealed that impact-loading physical activity is coupled with a better bone mineral density compared to nonimpact activities [12, 13].

In addition, sports participation involves a great number of muscle contractions, which produce forces and mechanical loads responsible for the bone adaptations [14]. Another important factor

is the intimate relationship between the union of muscle tissue with bone tissue, which, when contracted, can stimulate bone stress and consequently bone growth [12].

Physical inactivity is associated with muscular atrophy and the loss of bone mass and bone mineral density [15]. In general, sedentary people have lower bone mass than physically active individuals; however, the increases in bone mineral density and mass, resulting from either endurance or resistance training, are comparatively low [7]. Various types of exercise (e.g., resistance training, speed and endurance) have different effects on bone mineral density and mass [16, 17]. Nevertheless, even modest improvements in bone mass gained from endurance or resistance training can help prevent or ameliorate the process of osteoporosis [15]. In aerobic exercise, the osteocalcin level may be decreased by the fourth week and then recovered by the eighth week, however, deoxypyridinolin continues to decrease [18]. In resistance-based exercise, the levels of osteocalcin and deoxypyridinolin have been shown to be increased at both 4 weeks and 8 weeks [18]. As such, multiple factors, including type, intensity, and duration of exercise, have important effects on the rate of bone metabolism [19]. Moreover, the impact of additional loading (i.e., intense or moderate exercise) on the skeleton is both variable and only crudely understood. Bone response to exercise varies as a function of skeletal age, sex, diet, reproductive hormone status and nature of the activity [20]. Furthermore, in athletes, the practical goal of an exercise intervention is not merely to increase bone mass, but to reduce the incidence of sustaining fractures [15].

According to the International Association of Athletics Federations (*IAAF*), athletics is defined as a set of codified sporting events including running, jumping, throwing, and walking [21]. Thus, athletics is a versatile physical activity, which includes several disciplines, and few studies have investigated the impact of performing these different disciplines on bone turnover in elite male [16, 22] or female [23] athletes. Ryan et al. [22] observed that the markers of bone formation did not differ between highly trained female athletes and sedentary controls. In contrast, the markers of bone resorption were higher in the sedentary women compared to the athletes. However, markers of bone turnover were negatively associated with regions of bone mineral density (BMD) [22]. Indeed, levels of bone formation have been shown not to be elevated in athletes and levels of bone turnover may not be predictive of subsequent changes in bone mass in power athletes and endurance athletes [7, 16, 23]. However, the relationship between aerobic and anaerobic performance with bone biochemical markers of formation and resorption, considering gender differences, in athletes is not well characterized. Consequently, the aim of this cross-sectional study was to investigate the effects of sex and sport-discipline

(i.e., endurance vs. power) on physical fitness performance and bone biochemical markers of formation and resorption in young, sub-elite, track and field athletes. We hypothesized that physical bone biochemical markers and fitness performances would be better in sub-elite male athletes compared to sub-elite female athletes related to age and biological characteristics [7, 24, 25]. In addition, we expected better bone biochemical markers in power compared with endurance athletes due to the higher impact loads power athletes experience in daily training [17, 26].

METHODS

Participants: One hundred and forty-four track and field athletes (78 males aged 17.8 ± 1.6 years; 66 females aged 17.2 ± 1.9 years) volunteered to participate in this study. Participant characteristics are shown in Table 1. Male and female sub-elite athletes were recruited from eleven different track and field clubs and from the Tunisian youth national team. Participating athletes were from six regional athletic centers throughout Tunisia. On average, the athletes exercised eleven months per year for at least three years (3.9 ± 0.8 years), with four weekly 120 min sessions and one competition every 3 months. Athletes were included in the study sample only if they had participated in national/international track and field championships. The participating athletes were divided into two main groups: (i) Endurance group (EG) that included 67 (n=32 males, 35 females) long distance runners whose main events were the 5,000 and the 10,000 m run, and (ii) Power group (PG) that included 77 (n= 46 males, 31 females) whose main events were the sprint (60-m, 100-m) and jumping events. No significantly differences were found between the EG and PG group relative to weekly training volume.

All procedures were in accordance with the ethical standards of the latest version of the Helsinki Declaration. The protocol was approved by the Ethics Committee of the Rabta Hospital, Tunis, Tunisia, (approval number: IRB00005445, FWA00010074). All athletes filled out a questionnaire in which they reported their injury history that needed medical treatment. Moreover, the questionnaire additionally asked for the use of medication, known diseases, and daily consumption of dairy products. As exclusion criteria, we defined a priori the presence of chronic diseases (e.g., diabetes), usage of medication that affects the skeletal system. Written informed consent was obtained from the participants, and if necessary, from their parents/legal guardians prior to study participation.

Anthropometric parameters: The height and the body mass of each subject were measured by a portable stadiometer (Seca Model 225, Hanover, MD) and digital scale (Tanita, Tokyo, Japan), respectively. The total lean mass (kg) was measured by dual-energy X-ray absorptiometry whole body densitometry.

Puberty stage assessment: The puberty stage was used as indicator for biological maturity status. It was determined and recorded by a pediatrician experienced in the assessment of secondary sex characteristics according to the method of Tanner [27]. According to their pubescent status, the participating male and female athletes were ascribed to Tanner stage 5 (post pubertal) [27].

Physical fitness characteristics

Vertical jump: Each participant performed two kinds of maximal jumps: The squat jump (SqJ), starting with knees bent approximately at 90° and without previous counter movement, and the countermovement jump (CMJ), starting from a standing position allowing for counter movement with the intention of reaching a knee bending angle of around 90° just before vertical acceleration. All vertical jump heights were calculated based on the flight time [28]. Both flight time and contact time were measured with an Opto-Jump System device (Microgate Bolzano, Italy). The ICCs for test-retest trials were 0.93 and 0.95, for the SqJ and the CMJ, respectively.

Horizontal jump: For the standing long jump (SLJ), athletes stood behind the starting line and were instructed to push-off vigorously and jump forward as far as possible on the track. The distance jumped was measured in centimeters using a metal tape measure from the start line at take-off to the position of the heel upon landing. The ICC for test-retest trials was 0.95.

Linear sprint test: The time needed to cover 10-m and 30-m at maximum speed was measured with an infrared photoelectric cell (Cell Kit Speed Brower, USA) placed at the start-finish point and on the 10-m or 30-m, respectively, approximately 0.4 m above the ground, and with an accuracy of 0.001 s. The participants were motivated to run as fast as they could. They performed three trials in total, and 3-min of recovery was allowed between repetitions. The best (fastest) 30-m sprint time and the associated 10-m sprint time were selected for analysis. The ICCs for test-retest trials were 0.96, and 0.97, for 10-m, and 30-m, respectively.

Yo-Yo Intermittent Recovery Test Level 1: The Yo-Yo IRT Level 1 test was performed according to the processes described by Krustup et al. [29]. Specifically, the athletes performed a series of 20-m shuttle runs at a pace set by a calibrated audio metronome, with a 10 s standard rest interval between shuttles. The time allowed for the shuttle runs progressively decreased,

that is, the speed was augmented. The test was terminated when the athlete was unable to maintain the required speed. The distance covered in the shuttles was recorded for analysis. All tests were conducted by the same investigators, scheduled at the same time of day, conducted in the same order, and using the same apparatus.

Biochemical markers

All blood samples were obtained from the participants between 08:00 and 09:30 h, after an overnight fast. Blood samples were centrifuged (2100 x g 10 min), and serum samples were stored frozen at -20° C until analysis. The samples were shuffled before testing, and the level of each biomarker was measured in duplicates (average of duplicates was used for analysis).

Markers of bone formation:

Osteocalcin (OC) is biosynthesized and secreted by osteoblasts and is therefore considered a specific osteoblastic marker produced during bone synthesis. Serum levels of osteocalcin were determined using the N-MID osteocalcin ELISA. Inter and intra-assay CVs were 10.8% and 3.1%, respectively.

Total procollagen type 1 N-terminal propeptide) (P1NP). Serum levels of total P1NP were determined using electrochemiluminescence immunoassay “ECLIA” on Elecsys 2010 (Roche Diagnostic GmbH). This assay detects both intact mono- and trimetric forms (total P1NP). Norm values using this method for the P1NP are 16.27-73.87 ng/mL.

Markers of bone resorption:

Serum levels of C-telopeptide of the collagen of I type (CTX), as marker of bone resorption, has increased in popularity as it can be measured from blood samples on automated platforms, and given the increasing body of literature dealing with this biomarker, it may be regarded as the biomarker of choice to examine osteoclastic bone resorption activity [30]. Bone resorption was measured by the serum (Cross Laps ELISA, Nordic Bioscience, Diagnostics, Herlev, Denmark), and inter and intra-assay CVs were < 9%.

Statistical analyses

Means and standard deviations (SD) were used to describe all variables. Data were analyzed using multivariate analysis of variance (ANOVA) (2 [sex: males, females] x 2 [sport discipline: power, endurance]). The level of significance was set at $p < 0.05$. If significant main effects or interactions were present, Bonferroni post-hoc analyses were performed. Effect sizes were

calculated for all ANOVA with the use of partial eta-squared, where values of 0.01, 0.06, and 0.15 were considered as small, medium, and large cut-off points, respectively [31]. The difference in performance between EG and PG for male and female athletes, in each variable, was assessed using an independent t-test. Effect sizes (ESs) were calculated and characterized according to the following scale: ≤ 0.2 , trivial; $> 0.2-0.6$, small; $>0.6-1.2$, moderate; $>1.2-2.0$, large; and >2.0 , very large [32]. Intraclass correlation coefficients (ICCs) were obtained using a two-way (rater and subject) random effects model and interpreted as poor (0–0.49), moderate (0.5–0.69), high (0.7–0.89), and very high (0.9) [33]. Statistical analyses were performed using SPSS software statistical package (SPSS Inc., Chicago, IL, version. 16.0).

RESULTS

Participants

The anthropometric characteristics of both groups are shown in Table 1. No injuries were recorded during testing.

Physical fitness

A significant main effect for sex was detected for the considered variables (Table 2). Female athletes performed worse in sprinting ($p<0.001$), jumping ($p<0.03$ to 0.001), and the yo-yo test ($p<0.002$) compared with male athletes. Significant between subject effects for sport-discipline were observed for SLJ ($F = 23.30$; $p<0.001$; $\eta^2=0.14$), SqJ ($F = 53.63$; $p<0.001$; $\eta^2=0.28$), CMJ ($F = 45.98$ $p<0.001$; $\eta^2=0.25$), 10-m ($F = 22.43$ $p<0.001$; $\eta^2=0.11$), 30-m ($F = 25.20$ $p<0.001$; $\eta^2=0.12$), and the Yo-Yo test ($F = 17.57$; $p<0.001$; $\eta^2=0.11$) (Table 2). For jumping and sprinting tests, the PG performed better than the EG ($p<0.001$; $d= 0.81-1.27$, moderate to large). For the Yo-Yo test, endurance athletes had better performance than power athletes ($p<0.001$; $d=0.56$) moderate). No statistically significant sex-by-sport discipline interactions were observed for any of the assessed variables.

Biochemical markers

The biochemical markers of bone turnover are presented in Table 3. A significant main effect of sex was observed for CTx ($F=11.37$; $p<0.001$; $\eta^2=0.10$) for OC ($F=8.58$; $p<0.004$; $\eta^2=0.09$) and for P1NP ($F=7.96$; $p<0.004$; $\eta^2=0.07$). The average CTx, OC, and P1NP intakes were significantly higher in males compared to females ($p<0.05$ to 0.001).

In addition, a significant main effect of sport discipline was observed only for P1NP ($F=10.16$; $p<0.002$; $\eta^2=0.09$). No interactions (sex by sport discipline) were observed between sex and sport discipline ($p>0.05$; $\eta^2=0.67$)

257

258 **DISCUSSION**

259 In this cross-sectional study, we found that male sub-elite track and field athletes outperformed
260 female sub-elite athletes in measures of physical fitness, irrespective of the group under
261 consideration (endurance or power). The PG performed better than the EG in sprint and jump
262 tests. In addition, we showed that mean values for bone biochemical markers in PG compared
263 with EG were significantly higher in males vs. females.

264 For the purpose of physical fitness evaluation, the study sample (sub-elite track and field
265 athletes) was divided into an endurance and a power group, according to the main track and
266 field discipline, athletes practiced. Athletes were allocated to the endurance group if their sport
267 discipline mainly demanded the aerobic metabolism (e.g., long distance running) and they were
268 allocated to the power group if their discipline demanded the anaerobic metabolism (e.g., long
269 and high jump, sprint) [24, 34].

270 Compared to females, the male sub-elite athletes attained better results in the physical fitness
271 tests. Jump, endurance, and sprint ability are among the most important performance variables
272 in both male and female athletes. Indeed, the results of the present study showed significant
273 differences between male and female sub-elite athletes for sprint (10-m, 30-m), jump (SqJ,
274 CMJ, and SLJ), and endurance performance during the Yo-Yo test. The gender stratified
275 physical fitness results are similar to previous data, which typically shows poorer aerobic
276 capacity and muscular fitness for females compared to males [24, 35]. By analyzing the
277 performances of male sub-elite athletes, for sprinting and jumping tests, the PG performed
278 better than the EG. For the Yo-Yo test, the EG performed better than the PG. These results are
279 concordant with previous findings showing that these differences in short-term maximal
280 performances between male and female athletes could be explained by higher body fat, less
281 muscle mass, and maximum oxygen uptake ($\text{VO}_{2\text{max}}$), and lower levels of hemoglobin in
282 females, compared to males [24, 36]. Moreover, a lower training load in female athletes, less
283 training experience and lower training quality, may potentially explain the observed sex
284 differences in the current study. In addition, the gender differences may be explained by
285 differences in energy metabolisms (i.e., higher fat as well as less carbohydrate and amino acid
286 oxidation) in females compared to males [36, 37].

Differences in endurance performance have been reported to depend on training status, period of the season, and muscle power of the lower limbs in male soccer players [38]. Indeed, the gender differences observed in the present study could also be explained by differences, between male and female athletes, in the training status, length of the season, and the inclusion of power training for the lower limbs; in addition, differences in drafting strategy can influence athletic performances [39].

However, to our knowledge, limited research has examined the bone biochemical markers of formation and resorption associated with physical fitness performances for both male and female sub-elite athletes within the same study.

We sought to investigate variations in the bone biochemical markers in these athletes regardless of the intensity and duration of the exercise. In the present study, we chose serum OC and P1NP as bone formation markers and CTx as bone resorption markers. Serum levels of N-terminal propeptide of procollagen type I and osteocalcin are currently among the most compelling formation markers [5, 9]. The results of the current study suggest that a significant main effect of sex was observed for markers of bone formation and of bone resorption. Our data revealed that male sub-elite athletes have higher values in plasma formation of OC, P1NP and in plasma resorption of CTx compared to female sub-elite athletes. In the literature, it has been well established that prolonged mechanical loading increases bone mass, whilst brief exercise at low or high intensity does not seem to have an instant measurable impact on bone metabolic turnover in athletes [7], young boys [10], women [2] and old men [16].

Our results are also in agreement with several studies that have shown elevated levels of bone metabolic turnover in male athletes with different types of exercise (e.g., running, swimming, soccer) compared to female [7, 18, 23, 26]. Nevertheless, some studies have demonstrated the modification of bone metabolic turnover with sex difference in athlete's population [35, 40, 41]. Matsumoto et al. [35] showed that the status of bone metabolic turnover in male judo athletes in training may be hypermetabolic, as well as that of female judo athletes with regular menses cycles. In light of this statement, it is important to highlight that bone remodeling may be affected by the type of physical exercise.

In regard to the effect of sport-discipline and bone biochemical markers related to sex differences, the significant marker was observed only for P1NP values in favor of the EG vs. PG. The findings of our study are complemented by similar results by Malm et al. [42] who established that elite endurance runners induced an immediate variation in bone markers after

marathon running, an endurance activity that combines long duration and high intensity. Further, male athletes who practice sports generating high mechanical constraints on the body, present a specific bone metabolism that includes high bone mass, as well as high bone turnover [5]. This implies that bone remodeling may be affected by the type of physical exercise [7, 35]. Therefore, adding to the mechanical impact of physical exercise on bone turnover [5], exercise components such as training intensity (strength or endurance) [16, 26] and volume seem to be implicated [14]. Besides, sex difference may be modulating bone and collagen marker response [16, 18].

When compared to age-matched counterparts in both genders, our anthropometric data revealed that the females in the PG had significantly higher body mass and lean mass than the EG. Similarly, the males in the PG had significantly higher body mass and lean mass compared to the EG. As far as height is concerned, we found that female athletes in the PG were significantly taller than females in the EG.

For anthropometric characteristics (i.e., body height and body mass), the findings of the present study agreed with Matsumoto et al. [35] who showed that there were no significant differences in body composition between the two groups for male athletes. Furthermore, a significant difference in body composition was recognized between female athletes in the two groups (endurance vs. power). Moreover, in a previous study, it was reported that male athletes had a higher body-mass compared to female athletes [24].

Through this comparative study conducted on 78 males and 66 females (track and field athletes), the following results support the view that there is an association between bone remodeling activity, physical fitness parameters, and kind/type of sport practiced. However, the relative effects of these factors on the athletics performances and bone remodeling biochemical markers of males as compared to females remains to be fully explored, and clearly warrants further study.

The current study has some limitations. First, the cross-sectional design prevents us from analyzing any causal relationship, yet does enable a significant sample number (N = 144). In addition, a limitation of this study is that it did not adjust the analyses by intensity of training quantified and nutritional status, which are potential confounders [1, 8].

Finally, despite adjustment for initial confounding factors, we acknowledge that sport discipline may affect bone mineral density measures differently. Our analysis did examine sex-related differences. However, future studies may want to probe this issue in more depth by examining biological age post puberty to better to better examine sexual maturation.

In contrast, the strengths of the study comprise that it included a large sample of more than 140 young, sub-elite, track and field athletes with indicators of objectively measured bone biochemical markers and reliable assessment of physical fitness on different sex. In future investigations, it might be interesting to develop this study longitudinally so as to see if there is a cause–effect relation.

PRACTICAL APPLICATIONS

The results of this study suggest that anaerobic training (PG), throughout season results in positive changes in sprint and especially for jumping performances in female and male sub-elite athletes. However, aerobic training (EG) was effective in enhancing bone formation markers in young sub-elite track and field athletes related to gender. Examination of fitness profiles associated with bone biochemical markers in PG and EG could be a great importance of optimal construction of physical and technical qualities in formation programs. Further studies would be required to investigate the possible impact of training loads on physical development and bone remodeling markers in young track and field athletes. In addition, the effect of fitness level on performance during athletic events across the competitive standards of age categories and the gender.

CONCLUSION

The present study showed a beneficial association between different types of sport disciplines within track and field (power and endurance) on bone turnover markers (PINP, OC) in sub-elite athletes. Further, this study demonstrated that female and male sub-elite athletes differed in physical fitness performance, especially for jumping tests in the PG vs. EG. It appears that endurance athletics may contribute to changes in bone turnover related to gender.

Conflicts of interest: The authors have no conflicts of interest to declare.

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Table 1. Baseline characteristics of endurance and power athletes. Data are means \pm standard deviations (SDs).

Table 2. Field fitness test performance of endurance and power athletes.

Table 3. Biochemical markers of bone turnover between endurance and power athletes.

Table 1. Baseline characteristics of endurance and power athletes. Data are means \pm standard deviations (SDs).

		Endurance	Power
Variables		athletes (n=67)	athletes (n=77)
Age (years)	Males	17.7 \pm 2.2	17.9 \pm 1.3
	Females	17.0 \pm 2.4	17.5 \pm 1.8
	Total	17.3 \pm 2.3	17.7 \pm 1.5
Height (cm)	Males	169.3 \pm 9.9	173.4 \pm 8.7
	Females	161.8 \pm 6.9	166.7 \pm 5.5 **
	Total	165.4 \pm 9.2	170.7 \pm 8.2***
Body mass (kg)	Males	63.2 \pm 7.7	70.6 \pm 9.9**
	Females	55.9 \pm 8.1	63.5 \pm 8.4***
	Total	59.4 \pm 8.7	67.8 \pm 9.9***
Lean mass (kg)	Males	52.3 \pm 8.6	59.62 \pm 9.3**
	Females	45.0 \pm 8.0	51.66 \pm 7.97
	Total	48.5 \pm 9.0	56.42 \pm 9.57
Training volume (h/wk)	Males	8.0 \pm 1.2	8.00 \pm 0.8
	Females	8.0 \pm 0.5	7.85 \pm 0.5
	Total	8.0 \pm 0.9	7.92 \pm 0.6

Significant differences between endurance and power athletes: **: $p < 0.01$, ***: $p < 0.001$.

Table 2. Field fitness test performance of endurance and power athletes.

				Main effect p-value (η^2)		Interaction
Tests		Endurance athletes	Power athletes			Sex x Sport Discipline
				<i>Sex</i>	<i>Sport-Discipline</i>	p-value (η^2)
Sprint 10-m (s)	Males	1.88 ± 0.22	1.80 ± 0.36*	0.001	0.001	0.52
	Females	2.01 ± 0.23	1.91 ± 0.21*	(0.10)	(0.11)	(0.003)
	Total	1.94 ± 0.23	1.85 ± 0.29*			
Sprint 30-m (s)	Males	4.48 ± 0.47	4.40 ± 0.31*	0.001	0.001	0.43
	Females	4.91 ± 0.35	4.57 ± 0.61**	(0.09)	(0.12)	(0.004)
	Total	4.67 ± 0.52	4.48 ± 0.48*			
SLJ (cm)	Males	225.16 ± 18.63	239.15± 26.76**	0.001	0.001	0.22
	Females	196.77 ± 23.96	220.55 ± 23.24***	(0.20)	(0.14)	(0.001)
	Total	210.33±25.74	231.66±26.86***			
SqJ (cm)	Males	28.78 ± 7.63	36.69 ± 6.59***	0.03	0.001	0.52
	Females	25.67 ± 4.92	34.41 ± 6.68***	(0.08)	(0.28)	(0.003)
	Total	27.16±6.50	35.55±6.64***			
	Males	30.59 ± 7.00	37.80 ± 7.52***			

CMJ	Females	27.61 ± 4.87	35.63 ± 6.90***	0.02	0.001	0.76
	Total	29.04±6.12	36.71±7.32***	(0.07)	(0.25)	(0.001)
Yo-Yo	Males	2040 ± 202**	1669 ± 157	0.003	0.001	0.93
IR1 (m)	Females	1680 ± 169*	1327 ± 224	(0.09)	(0.11)	(0.001)
	Total	1835 ± 598 ***	1498 ± 614			

SLJ: Standing long jump (cm); SqJ: Squat jump test (cm); CMJ: Counter-movement jump (cm); Yo-Yo IR1: Yo-Yo intermittent recovery test level-1 (m);

Significant main effects of sex or sport discipline; *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$.

Table 3. Biochemical markers of bone turnover between endurance and power athletes.

Markers		Endurance athletes	Power athletes	Main effect p-value (η^2)		Interaction
				Sex	Sport discipline	Sex x Sport Discipline p-value (η^2)
CTx (μ /l)	Males	0.31 \pm 0.20	0.33 \pm 0.16	0.001	0.787	0.634
	Females	0.23 \pm 0.14	0.23 \pm 0.10	(0.10)	(0.001)	(0.002)
	Total	0.27 \pm 0.18	0.29 \pm 0.15			
OC (ng/ml)	Males	37.58 \pm 18.83	35.19 \pm 15.50*	0.004	0.184	0.423
	Females	32.02 \pm 17.51	26.42 \pm 7.05*	(0.09)	(0.013)	(0.005)
	Total	34.68 \pm 18.23	32.26 \pm 13.60*			
P1NP (ng/ml)	Males	278.47 \pm 239.13	194.23 \pm 110.24*	0.05	0.002	0.996
	Females	225.74 \pm 166.07	141.24 \pm 78.77**	(0.07)	(0.09)	(0.000)
	Total	250.92 \pm 204.38	172.89 \pm 101.99**			

CTx: C-telopeptide type I collagen (μl); OC: serum osteocalcin (ng/ml); PINP: N-terminal propeptide of procollagen type I (ng/ml).

Significant main effects of sex or sport discipline and sex-by-sport discipline interactions: *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$.