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Combined effects of bee pollen supplementation and resistance training on aerobic capacity, muscular performance, antioxidant status, and bone metabolism markers in young men: A randomised controlled trial

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ABSTRACT

Introduction: This study investigated the combined effects of bee pollen and resistance training on aerobic capacity, muscular performance, antioxidant status, and bone metabolism markers among young men. **Methods:** Forty young men were randomly assigned into four groups: sedentary control (C), bee pollen supplementation (BP), resistance training (RT), and combined bee pollen supplementation and resistance training (BPRT) groups. Bee pollen was consumed by participants in BP and BPRT groups (1500 mg daily for eight weeks). Resistance training was performed thrice per week for eight weeks in RT and BPRT groups. Participants' anthropometry, aerobic capacity, isokinetic muscular peak torque (strength), and average power were measured. Concentrations of serum total antioxidant status (TAS), serum superoxide dismutase (SOD), serum alkaline phosphatase (ALP), and serum C-terminal telopeptide of type 1 collagen (1CTP) were determined. **Results:** After eight weeks of intervention, there was a significant decrease in 1CTP in BP group. In RT group, significant increases were observed in both muscular strength and power. In BPRT group, significant increases in both muscular strength and power, and a significant decrease in 1CTP were observed after 8 weeks. There were no significant changes in aerobic capacity, serum TAS, SOD, and ALP in all the study groups. **Conclusion:** Resistance training using dumbbells and elastic bands seemed to elicit beneficial effects on muscular strength and power, while bee pollen supplementation alone reduced the level of bone resorption marker. In addition, combining bee pollen with resistance training seemed to offer additive benefit in muscular strength and power.

Keywords: antioxidant status, bee pollen, bone metabolism markers, muscular performance, resistance training

INTRODUCTION

Bee pollen is naturally produced in pellet form with its own particular case and placed in the cells of honeycomb (Komosinska-Vassev *et al.*, 2015). It has been demonstrated that bee

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pollen contains phenolic compounds which have significant antioxidant activities, thereby making it a potential nutraceutical product (Mărgăoan *et al.*, 2019; Barbieri *et al.*, 2020). Antioxidants act to prevent cellular damage that can cause cancer, ageing, and other diseases. The interaction between antioxidants and free radicals can terminate the chain reaction before vital molecules are damaged (Damir *et al.*, 2014). It has been well-documented that some types of exercise or training and/or nutritional supplementation can enhance the antioxidant system, such as total antioxidant status (TAS) (Tartibian & Maleki, 2012; Tavafzadeh *et al.*, 2015) and superoxide dismutase (SOD) activity (Wadiah *et al.*, 2015).

Bee pollen has been reported to provide a source of energy and protein to humans (Campos *et al.*, 2010). Ivy *et al.* (2002) recommended the addition of protein to carbohydrate supplements as this can enhance muscle glycogen storage during heavy exercises. Therefore, it is speculated that the protein contained in bee pollen may give positive effects on certain physiological parameters when combined with resistance training. Regarding bee pollen and bone health, Kafadar *et al.* (2012) have demonstrated that bee pollen could decrease bone loss in ovariectomised rats. Bone loss may occur when the bones are not frequently used for movement (Burr, 1997). Smith & Gilligan (1991) mentioned that being physically active and consuming a proper diet can reduce bone loss to prevent osteoporosis during ageing. In terms of bone metabolism, changes in bone formation markers and bone resorption markers have been investigated in previous studies involving exercise or training and nutritional supplementation (Ooi, Ismail & Abdullah, 2011; Wadiah *et al.*, 2015; Rahim, Ooi & Hamid, 2016).

It is generally known that resistance training involves the contraction of particular muscles with resistance such as dumbbells, elastic bands or one's own body weight. Resistance training is believed to increase muscular strength, tone, mass, and endurance. Kwon *et al.* (2010) demonstrated that resistance training using elastic bands allows an individual to start using bands that are more elastic and gradually increasing the intensity by using bands with less elasticity as muscular strength increases. Previous studies have also indicated that muscular strength and power can be increased with physical training (Rahim *et al.*, 2016), as well as when training is combined with nutritional supplementation (Lau & Ooi, 2014; Chen *et al.*, 2016). A recent study demonstrated that two weeks of resistance training and bee pollen supplementation (10 g daily) resulted in a significant reduction in total cholesterol, triglycerides, and low-density proteins in young men (Abbass, Mahdi & Mohammad Javad, 2020).

To date, data on the effects of bee pollen supplementation and its combined effect with resistance training on aerobic capacity, muscular performance, antioxidant status, and bone metabolism markers are scarce. Thus, the primary objective of this study was to investigate the combined effects of bee pollen and resistance training on aerobic capacity and muscular performance in young men. In addition, the secondary objective of this study was to investigate the effects of bee pollen combined with resistance training on the antioxidant status and bone metabolism markers in young men. The hypothesis of this study was that significant differences will be observed between the combined bee pollen supplementation and resistance training group compared with the bee pollen supplementation alone, resistance training alone, and control groups in aerobic capacity, muscular strength and

average power, antioxidant status, and bone metabolism markers in young men after eight weeks of intervention.

MATERIALS AND METHODS

Forty physically healthy men aged between 19 to 26 years old from the Health Campus of Universiti Sains Malaysia in Kubang Kerian, Kelantan, were recruited in this study. Sample size was calculated by using G*power software version 3.0.10., based on a previous study by Wadiah *et al.* (2015) with mean difference of 0.2 and standard deviation (*SD*) of 0.64. All participants were age-matched and then randomly assigned via parallel randomisation into four groups, with ten participants per group. The participants were given detailed explanation about the objectives, procedures, benefits and risks, as well as possible discomforts and adverse effects that might be experienced during the study before signing the informed consent forms. This study was approved by the Human Research Ethics Committee, Universiti Sains Malaysia (Ref: USM/JEPeM/16020076).

The four groups of participants were: (i) sedentary without bee pollen supplementation and resistance training (C); (ii) bee pollen supplementation (BP); (iii) resistance training (RT), and (iv) combined bee pollen and resistance training (BPRT) groups. Participants in the C group did not perform any resistance training or consume any bee pollen supplements during the study period. Participants in the BP group consumed 1500 mg of bee pollen daily for eight weeks and did not perform any form of physical training. Participants in the RT group were required to perform three sessions per week of resistance training for eight weeks, while participants in the BPRT group were required to consume 1500 mg of bee pollen daily and perform three sessions per week of resistance training for eight weeks. All the participants were instructed not to consume any other types of supplements during the study period.

Anthropometric measurements were recorded at pre- and post-experimental period. Body weight, height, body mass index (BMI), and percentage body fat were measured using an electronic weighing machine (SECA 220, Germany) and a bioelectrical impedance analyser (Tanita® TBF-410, Japan). For the supplementation regimen in this study, Forever Bee Pollen® was used. This product is sold commercially, and it is registered with the National Pharmaceutical Regulatory Agency. The dosage of bee pollen consumed by the participants was 1500mg per day as prescribed by the manufacturer. The nutritional composition of bee pollen includes protein (13.8g/100g), total fat (6.3g/100g), total carbohydrate (68.0g/100g), energy (1613Kcal/100g), fructose (10.0g/100g), and glucose (8.4g/100g).

The resistance training programme was designed with ten stations of different exercises using either elastic bands or dumbbells based on a similar training method described by Chen *et al.* (2019). The types of exercises were biceps curl with dumbbells, leg curl with elastic band, front raise with dumbbells, knee extension with elastic band, standing chest fly with dumbbells, half squat with elastic band, triceps extension with dumbbell, leg abduction with elastic band, shoulder flexion with elastic band, and heel raise with dumbbells. The number of repetitions for exercises with dumbbells and elastic bands were 10 and 15, respectively. The weight of the dumbbells was between 3-10 kg, while the elastic bands were colour-coded in terms of their elasticity. For the first four weeks, the participants were instructed to use dumbbell weights

according to their initial strength level, while for elastic bands, they were told to use the colour-coded bands with lower resistance (more elastic). A three-minute rest was given to the participants before they performed a subsequent set of exercise. The participants were required to complete three sets of this circuit per session and this training programme was conducted three sessions per week for eight weeks. The intensity of the resistance training was increased after four weeks by using heavier dumbbells and elastic bands with less elasticity.

Participants' aerobic capacity was determined via a 20 m shuttle run test. The test was conducted before and after the eight weeks of intervention period. The equipment used to conduct the test included measuring tape, marker cones, CD player, and pre-recorded CD. The test started with ten minutes of warm-up and ended with five minutes of cooling down. After warm-up, the participants ran on a flat cement surface of 20 m distance that had been marked with cones until they were volitionally exhausted. The estimated maximal oxygen consumption (VO_{2max}) of the participants was calculated based on the number of shuttles completed by each participant (Paradisis *et al.*, 2014). An isokinetic dynamometer (Biodex Multi-Joint System 3 Pro, New York, USA) was used to measure the isokinetic peak torque (an indicator of muscular strength) and average power of the participants. Two different angular velocities ($60°.s^{-1}$ and $300°.s^{-1}$) were used to measure the participants' knee flexion and extension isokinetic peak torque and average power of the non-dominant leg, as well as shoulder flexion and extension isokinetic peak torque and average power of the non-dominant arm before and after eight weeks of intervention. The non-dominant leg and arm were used in this study as previous studies have shown that there was no difference between isokinetic strength between the dominant and non-dominant limbs (Abdelmohsen, 2019; Cengizel, 2019).

Six ml of blood sample was taken from each participant before and after the eight-week intervention period. Blood was taken from the antecubital vein of the participants after a 12-hour overnight fast by a laboratory technologist at the Sports Science Laboratory. The blood taken was used to determine the concentrations of blood antioxidant status – total antioxidant status (TAS) and superoxide dismutase (SOD), as well as bone metabolism markers, which were alkaline phosphatase (ALP) for bone formation and C-terminal telopeptide of type 1 collagen (1CTP) for bone resorption. Blood samples were centrifuged and serum was collected and stored at -80 °C for subsequent blood biochemical analysis. The serum was analysed for TAS by using the QuantiChromTM Antioxidant Assay Kit (BioAssay Systems, USA), SOD by using the EnzyChromTM Superoxide Dismutase Assay Kit (BioAssay Systems, USA), ALP by using commercially available reagent kit (Randox, UK), and 1CTP by using quantitative enzyme immunoassay kit (ELISA Kit 1CTP EZA, China). The intra-assay coefficients of variation for TAS, SOD, ALP, and 1CTP were 4.6%, 3.2%, 3.4%, and 6.0%, respectively.

Statistical analysis was performed by using Statistical Package for Social Sciences (SPSS) version 23.0. All values were presented as mean±*SD*. Mixed analysis of variance (ANOVA) was performed to determine the differences between and within groups. Statistical significance was accepted at $p<0.05$.

RESULTS

Physical characteristics of the participants

The present study was completed with the participation of 40 sedentary young

Table 1. Baseline anthropometric characteristics and physiological parameters of all participants

Parameters	*Groups*			
	Control (C) (n=10)	*Bee pollen (BP) (n=10)*	*Resistance training (RT) (n=10)*	*Combined (BPRT) (n=10)*
Age (years)	21.8±2.1	22.0±1.9	22.0±2.7	20.4±0.8
Body weight (kg)	60.2±13.9	56.2±13.9	66.9±14.8	58.3±11.8
Body height (cm)	167.2±6.9	164.8±6.2	168.1±4.7	168.2±6.0
Body mass index (BMI) ($kg.m^{-2}$)	21.5±4.6	20.4±3.9	23.6±4.7	20.7±4.9
Percentage of body fat (%)	20.2±8.1	17.7±8.2	21.7±7.5	17.1±7.0
Fat free mass (FFM) (kg)	47.0±5.9	45.4±7.4	51.5±6.9	47.7±5.6

men with mean age of 21.6±2.1 years and mean body weight of 60.4±13.7 kg. All participants completed the study without any drop-out. Anthropometric data obtained from all participants (*N*=40) are summarised in Table 1.

There were no significant differences between groups in age, body height, body weight, and body fat percentage at the beginning and at the end of the experimental period (Table 1).

Compliance to bee pollen supplementation and resistance training programme

From the record of supplements consumed by the participants, the compliance of bee pollen supplementation was between 89.3 – 100%, while the attendance record for the resistance training programme indicated that the compliance of the participants was between 83.3 – 100% (minimum 20 training sessions out of 24).

Aerobic capacity

At pre-test, there were no significant differences in mean predicted VO_{2max} among all groups compared to the C group. There was no significant interaction effect of time and intervention

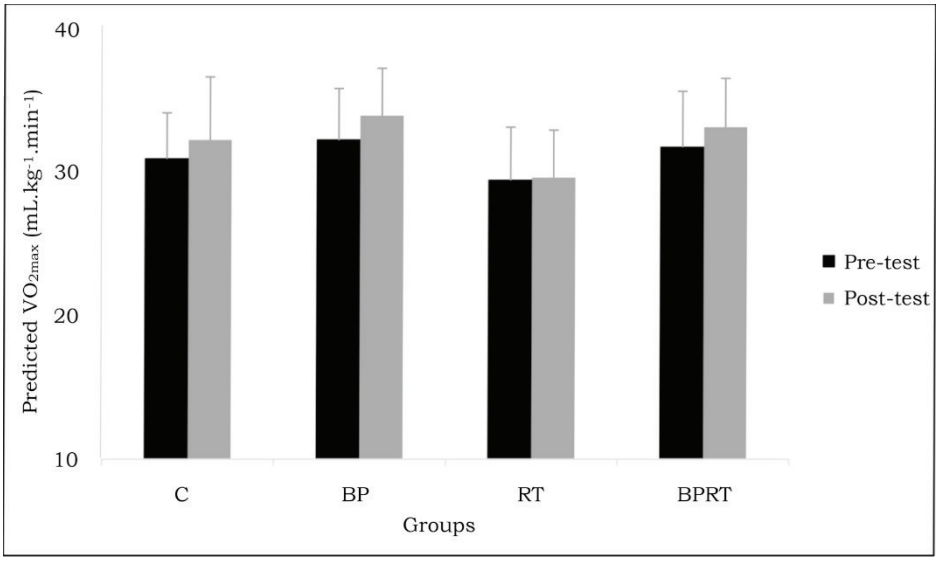

Figure 1. Mean predicted VO_{2max} at pre-test and post-test

Table 2. Mean isokinetic peak torque of knee and shoulder extension and flexion at pre-test and post-test (Mean±*SD*)

A) Mean isokinetic peak torque of knee extension and flexion at 60°.s^{-1} at pre-test and post-test

Groups	*Knee extension peak torque (N.m)*		*Knee flexion peak torque (N.m)*	
	Pre-test	*Post-test*	*Pre-test*	*Post-test*
C	127.4±32.7	137.2±25.9	62.8±19.6	68.7±17.4
BP	141.4±39.9	141.9±29.6	69.9±16.2	69.1±14.9
RT	151.6±21.2	180.7±35.4$^{***,++,‡‡}$	72.5±20.2	84.5±15.5$^{*,+,‡}$
BPRT	128.8±27.0	168.5±33.9$^{***,+}$	62.4±18.3	80.8±15.0***

B) Mean isokinetic average power of knee extension and flexion at 300°.s^{-1} at pre-test and post-test

Groups	*Knee extension average power (Watts)*		*Knee flexion average power (Watts)*	
	Pre-test	*Post-test*	*Pre-test*	*Post-test*
C	162.0±45.3	185.5±46.8	115.9±56.8	116.2±64.1
BP	181.9±56.1	219.5±52.9**	104.2±28.9	105.2±27.3
RT	192.4±60.3	274.7±68.3$^{***,+,‡}$	108.2±46.0	141.8±45.0**
BPRT	164.4±66.1	244.7±58.9$^{***,+}$	95.8±43.7	139.3±35.6***

C) Mean isokinetic peak torque of shoulder extension and flexion at 60°.s^{-1} at pre-test and post-test

Groups	*Shoulder extension peak torque (N.m)*		*Shoulder flexion peak torque (N.m)*	
	Pre-test	*Post-test*	*Pre-test*	*Post-test*
C	50.9±12.4	55.9±14.3	49.3±8.8	40.9±7.3
BP	43.0±9.7	43.0±11.9	39.5±6.6^{+}	47.9±9.8
RT	56.7±18.3‡	63.8±19.2‡	48.5±10.4‡	59.7±18.5$^{+,‡}$
BPRT	49.4±13.1	55.5±12.7	48.7±9.6‡	49.1±10.0

D) Mean isokinetic average power of shoulder extension and flexion at 300°.s^{-1} at pre-test and post-test

Groups	*Shoulder extension average power (Watts)*		*Shoulder flexion average power (Watts)*	
	Pre-test	*Post-test*	*Pre-test*	*Post-test*
C	54.5±29.1	71.6±20.6	59.2±20.1	64.1±18.9
BP	51.5±24.6	57.2±32.2	60.5±12.7	65.0±10.1
RT	74.1±34.4	106.7±58.6	65.8±22.0	84.5±23.8$^{***,+}$
BPRT	57.9±37.1	87.7±41.9	64.0±23.7	83.8±24.7$^{***,+}$

$^{*, **, ***}$significantly different from pre-test (p<0.05, p<0.01, p<0.001 respectively)
$^{+, ++}$significantly different from respective C group (p<0.05, p<0.01 respectively)
$^{‡, ‡‡}$significantly different from respective BP group (p<0.05, p<0.01 respectively)

in mean predicted VO_{2max} (df=3, F=0.763, p=0.522) among all groups (Figure 1).

Knee extension and flexion isokinetic peak torque at 60°.s^{-1}

There were no significant differences in mean isokinetic peak torque of knee extension at 60°.s^{-1} at pre-test between all groups (Table 2A). Mean isokinetic peak torque of knee extension at 60°.s^{-1} in RT (p<0.001) and BPRT (p<0.001) groups were significantly higher at post-test compared to their respective pre-test values. At post-test, isokinetic peak torque of knee extension at 60°.s^{-1} in RT and BPRT groups were significantly higher (p<0.01 and p<0.05, respectively) compared to C group, and significantly higher in RT group (p<0.01) compared to BP group.

There were no significant differences in mean isokinetic peak torque of knee flexion at 60°.s^{-1} at pre-test among all groups (Table 2A). At post-test, isokinetic peak torque of knee flexion at 60°.s^{-1} in RT group was significantly higher (p<0.05) compared to C and BP groups. Isokinetic peak torque of knee flexion at 60°.s^{-1} in RT and BPRT groups increased significantly (p<0.05 and p<0.001, respectively) compared to their respective pre-test values.

Isokinetic average power of knee extension and flexion at 300°.s^{-1}

There were no significant differences in mean isokinetic average power of knee extension at 300°.s^{-1} at pre-test among all groups (Table 2B). At post-test, isokinetic average power of knee extension at 300°.s^{-1} in RT and BPRT groups were significantly (p<0.05) higher compared to C group, and higher (p<0.05) in RT group compared to BP group. Isokinetic average power of knee extension at 300°.s^{-1} in BP, RT, and BPRT groups increased significantly (p<0.01, p<0.001, and p<0.001, respectively) compared to their respective pre-test values.

There were no significant differences in mean isokinetic average power of knee flexion at 300°.s^{-1} at pre-test among all groups (Table 2B). Isokinetic average power of knee flexion at 300°.s^{-1} in RT and BPRT groups increased significantly (p<0.01 and p<0.001, respectively) compared to their respective pre-test values.

Isokinetic peak torque of shoulder extension and flexion at 60°.s^{-1}

At pre-test, the isokinetic peak torque of shoulder extension at 60°.s^{-1} in RT group was significantly higher than BP group (p<0.05) (Table 2C). At post-test, isokinetic peak torque of shoulder extension in RT group was significantly higher than BP group (p<0.05). There were no significant changes in mean isokinetic peak torque of shoulder extension at 60°.s^{-1} among all groups compared to their respective resting values.

At pre-test, the isokinetic peak torque of shoulder flexion at 60°.s^{-1} in BP group was significantly lower than C, RT, and BPRT groups (p<0.05) (Table 2C). At post-test, the isokinetic peak torque of shoulder flexion at 60°.s^{-1} in RT group was significantly (p<0.05) higher than C and BP groups. There were no significant changes in mean isokinetic peak torque of shoulder flexion at 60°.s^{-1} among all groups compared to their respective resting values.

Isokinetic average power of shoulder extension and flexion at 300°.s^{-1}

There were no significant differences in mean isokinetic average power of shoulder extension at 300°.s^{-1} at pre-test among all groups (Table 2D). At post-test, isokinetic average power of shoulder extension at 300°.s^{-1} increased significantly in RT and BPRT groups (p<0.01) compared to their respective pre-test values. Isokinetic average power of shoulder extension at 300°.s^{-1} was

also significantly higher (p<0.05) in RT group compared to C and BP groups, and higher (p<0.05) in BPRT group compared to BP group.

There were no significant differences in mean isokinetic average power of shoulder flexion at 300°.s^{-1} at pre-test among all groups (Table 2D). At post-test, the isokinetic average power of shoulder flexion of 300°.s^{-1} in RT and BPRT groups were significantly (p<0.5) higher compared to C group. Isokinetic average power of shoulder flexion at 300°.s^{-1} in RT and BPRT groups increased significantly (p<0.001) compared to their respective pre-test values.

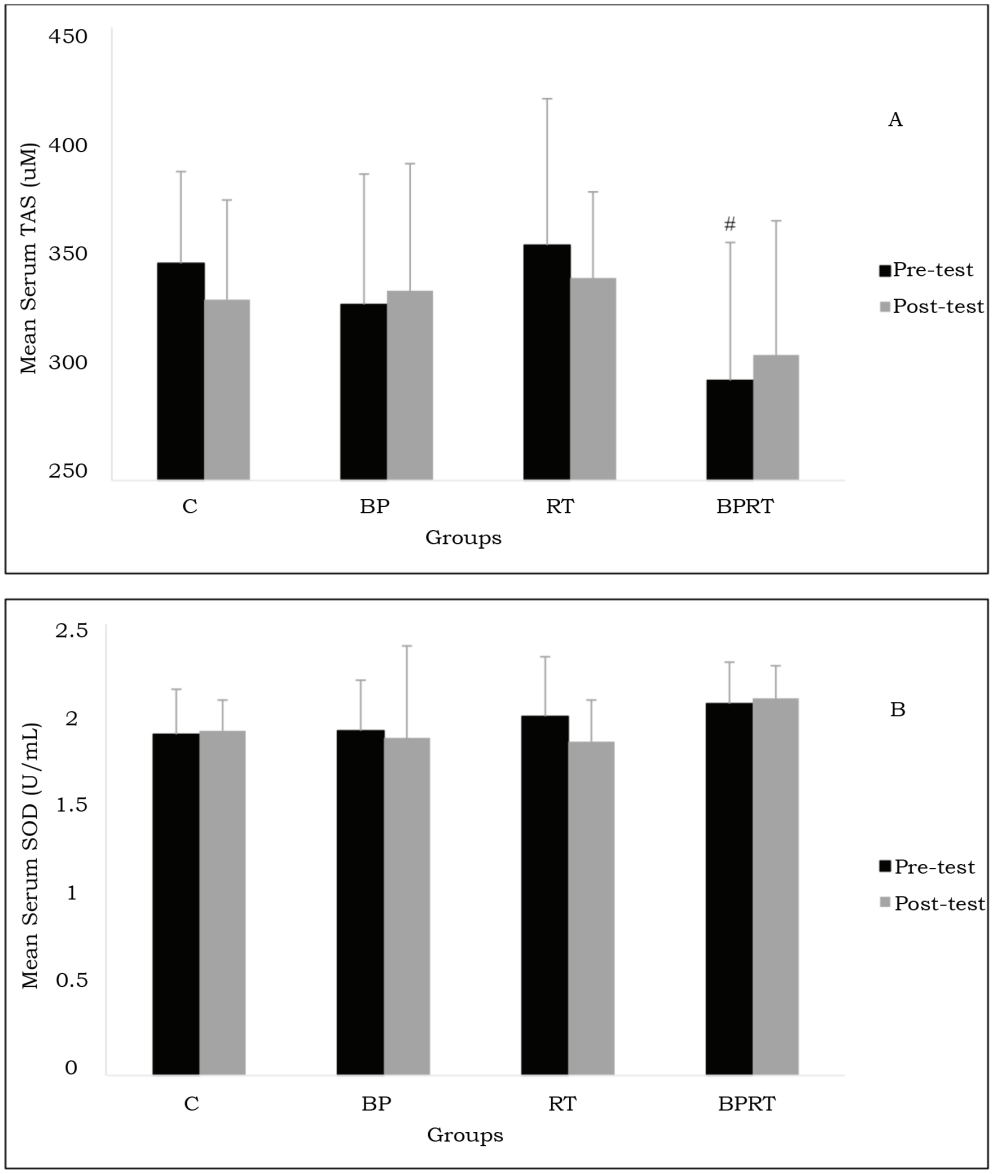

Figure 2. Mean serum total antioxidant status (TAS) (A) and mean serum superoxide dismutase (SOD) (B) at pre-test and post-test
#significantly different from RT group at pre-test (p<0.05)

Serum total antioxidant status (TAS) and superoxide dismutase (SOD)

At pre-test, mean serum TAS in BP group was significantly (p<0.05) lower than RT group (Figure 2A). There was no significant interaction effect of time and intervention in serum TAS (df=3, F=2.46, p=0.078). There was no significant effect of time on mean serum TAS between pre- and post-tests (df=1, F=1.004, p=0.323). Similarly, there was no significant effect of intervention in mean serum TAS among all groups at post-test. Regarding SOD, there was no significant difference in mean serum SOD among all groups at pre- and post-tests (Figure 2B). There was no significant interaction effect of time and intervention on serum SOD (df=3, F=0.425, p=0.736). There was no significant effect of time on mean serum SOD between pre- and post-tests (df=1, F=0.357, p=0.554). In addition, there was no significant effect of intervention on serum SOD among all groups at post-test.

Serum alkaline phosphatase (ALP) (bone formation marker) and C-terminal telopeptide of type 1 collagen (1CTP) (bone resorption marker)

There were no significant differences in mean serum ALP among all the experimental groups at pre- and post-tests (Table 3). There was no significant interaction effect of time and intervention in mean serum ALP (df=3, F=1.664, p=0.192) among all groups. There was also no significant effect of time on mean serum ALP between pre- and post-tests (df=3, F=1.082, p=0.369). Similarly, there was no significant effect of intervention in mean serum ALP (df=3, F=1.051, p=0.382) among all groups.

At pre-test, mean serum 1CTP in RT group was significantly (p<0.01) lower compared to BP group (Table 3). There was a significant interaction effect of time and intervention on mean serum 1CTP (df=3, F=4.119, p=0.013) among all groups. In addition, there was a significant effect of time on mean serum 1CTP between pre- and post-tests (df=1, F=10.069, p=0.003). However, there was no significant effect of intervention in mean serum 1CTP (df=3, F=0.839, p=0.481) among all groups.

DISCUSSION

In the present study, bee pollen supplementation alone, resistance training alone, and combined bee pollen supplementation and resistance training for eight weeks did not elicit any effects on estimated maximal oxygen consumption (VO_{2max}), which is an indicator of aerobic capacity (Figure 1). The results of no improvement in maximal oxygen consumption following bee pollen supplementation in this study was consistent with a previous study where bee pollen supplementation after six weeks did not show any significant

Table 3. Mean serum alkaline phosphatase (ALP) and mean serum C-terminal telopeptide of type 1 collagen (1CTP) at pre-test and post-test (Mean±*SD*)

Groups	*Serum ALP (U/L)*		*Serum 1CTP (ng/mL)*	
	Pre-test	*Post-test*	*Pre-test*	*Post-test*
C	73.6±26.6	76.8±25.8	6.1±2.3	4.8±1.1
BP	69.2±21.1	69.7±19.6	8.5±5.2	4.9±2.7**
RT	63.9±16.9	64.9±15.0	4.4±1.4§	5.5±4.2
BPRT	81.2±22.4	79.3±22.3	7.3±2.8	4.9±2.3*

*, **, significantly different from respective pre-test values (p<0.05, p<0.01 respectively)
§ significantly different from BP group at pre-test (p<0.01)

improvement in VO_{2max} among adolescent swimmers (Maughan & Evans, 1982). Thus, this demonstrated that the macronutrients contained in bee pollen did not offer beneficial effects on aerobic capacity.

However, the present study indicated that resistance training alone, and combined bee pollen supplementation and resistance training elicited some beneficial effects on both muscular strength and power of the lower and upper limbs despite the absence of statistical significance in some of the groups (Table 2 A, B, C, and D). Thus, the prescribed resistance training programme alone and when combined with bee pollen supplementation in this study seemed to be effective in improving muscular strength. However, the combination of bee pollen supplementation and resistance training did not provide additional effect in enhancing muscular strength. Similar findings of increased muscular strength have been reported in previous studies using different nutritional supplements. Circuit training alone, and combined *Eurycoma longifolia Jack* supplementation (400 mg per day for seven days per week) plus circuit training significantly increased the muscular strength of knee flexion and knee extension following eight weeks of intervention (Ooi *et al.*, 2015). In contrast with the present finding, 12 weeks of resistance training at two days per week did not show any significant increase in peak torque on knee flexion and extension in adolescent *taekwondo* athletes (Teng *et al.*, 2008). This difference could be attributed to the fitness levels of the participants, training frequency, and types of exercises carried out in these studies.

The current study findings also demonstrated that resistance training alone, and combined bee pollen supplementation and resistance training elicited beneficial effects on muscular power through increased isokinetic average power of knee extension and flexion, as well as shoulder flexion (Tables 2). Similar findings of increased muscular power have been reported in previous studies when resistance training was combined with other nutritional supplements (Ooi *et al.*, 2015; Chen *et al.*, 2016). Combined *Eurycoma longifolia Jack* supplementation and circuit training for eight weeks significantly increased the isokinetic muscular power of knee and shoulder extension (Ooi *et al.*, 2015). Another study also reported that combined *Lignosus rhinocerotis* supplementation (500 mg daily) with resistance training significantly increased muscular power among young males (Chen *et al.*, 2016). In the present study, there was no significant difference in average power between the resistance training group and the combined bee pollen supplementation and resistance training group, implying that bee pollen consumption did not offer additive effect in enhancing average power.

In the present study, all three interventions, i.e. bee pollen supplementation alone, resistance training alone, and combined bee pollen supplementation and resistance training did not affect serum TAS (Figure 2). These results implied that these interventions for eight weeks did not elicit significant effect on total antioxidant status in the blood. However, a previous study showed contradictory finding where honey supplementation during eight weeks of intensive cycling training increased serum total antioxidant status in non-professional male road cyclists (Tartibian & Maleki, 2012). The difference in the present finding with the previous study may be attributed to differences in the types of supplements and training protocols used.

The present study demonstrated that bee pollen supplementation alone, resistance training alone, and

combined bee pollen supplementation and resistance training did not affect serum SOD (Figure 2). Similar findings were also reported in other studies with different nutritional supplementation and different exercise modes (Tauler *et al.*, 2006; Wadiah *et al.*, 2015). For instance, SOD activity was not affected when chocolate malt drink consumption was combined with aerobic dance exercise (Wadiah *et al.*, 2015). Similarly, erythrocyte and lymphocyte SOD activity levels did not show any significant difference after the consumption of selenium supplement combined with intense exercise (Tauler *et al.*, 2006). In contrast, other studies reported that serum SOD activity was increased following a bout of training (Sahrir *et al.*, 2017; Wiecek *et al.*, 2018; Yan & Spaulding, 2020). Nevertheless, our data indicated that neither the prescribed resistance training programme or bee pollen supplementation alone, nor the combination of both affected SOD activity. Thus, it was shown that bee pollen supplement, which contains phenolic compounds and carotenoids that act as antioxidants, was not adequate to elicit any effect on the SOD activity in this study.

We also observed that there were no significant differences in serum ALP concentrations after eight weeks of experimental period in all four experimental groups (Table 3). The prescribed resistance training programme and the dosage of bee pollen given in this study did not affect serum ALP (a bone formation marker). Similar finding has been reported where aerobic dance exercise at three times a week for six weeks also did not affect serum ALP in young females (Ooi *et al.,* 2011). However, the present finding was in contrast with a previous study by Wadiah *et al.* (2015), where serum ALP increased with another nutritional supplementation and different exercise modes. In their study, it was observed that chocolate malt drink supplementation alone, aerobic dance exercise alone, and combined chocolate malt drink supplementation and aerobic dance exercise elicited increased serum ALP in their female participants. The difference between the present finding with this previous study is likely due to differences in types of supplements and exercises used.

Serum 1CTP was significantly lower in post-test compared to pre-test value in bee pollen supplementation alone, and combined bee pollen supplementation and resistance training groups (Table 3). The present data indicated that bee pollen supplementation alone and when combined with resistance training reduced the levels of serum 1CTP, a bone resorption marker. This finding was consistent with a previous study where the excretion of bone resorption markers (pyridinoline and deoxypyridinoline) decreased significantly after the consumption of soybean isoflavone supplement (Uesugi *et al.*, 2002). These data implied that nutritional supplementations may elicit beneficial effects on bone health by reducing bone resorption markers. Lau & Ooi (2014) have also shown that there was a significant reduction in 1CTP after six weeks of circuit training programme combined with consumption of chocolate milk supplement. These data indicated that bone metabolism markers are not only affected by nutritional supplements, but also by the combined effect of nutritional supplementation with certain types of training.

In summary, the consumption of bee pollen at a dosage of 1500mg daily for eight weeks did not provide any beneficial effect in some of the parameters measured in the present study. Hence, it is postulated that these observations could be attributed to inadequate dosage of bee pollen given to the participants and/or insufficient

duration of the intervention period. Thus, the limitations of the present study are as follow: i) no dose response of bee pollen supplementation was performed; ii) the intervention period of this study was only eight weeks; iii) only one biomarker was used to determine bone formation and another biomarker for bone resorption; and iv) the lack of micronutrient data on bee pollen supplements.

CONCLUSION

The prescribed resistance training programme using dumbbells and elastic bands at three times per week for eight weeks elicited increases in muscular strength and power. Bee pollen supplementation at a dosage of 1500 mg per day (as prescribed by the manufacturer of this product) for eight weeks seemed to reduce the bone resorption marker. However, when bee pollen supplementation was combined with resistance training programme, additional benefits were not observed in aerobic capacity, muscular performance, antioxidant status, and bone metabolism markers. Under the conditions set up in this study, it is concluded that resistance training using dumbbells and elastic bands conferred beneficial effects on muscular strength and power, while bee pollen supplementation alone reduced the level of bone resorption marker.

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Authors' contributions

NN, conducted the study, data analysis and interpretation, drafting of the manuscript; CCK, conceptualised and designed the study, reviewed the manuscript; OFK, conceptualised and designed the study, data analysis, reviewed the manuscript; MM, designed the study, reviewed the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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