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A controlled clinical study of product PINOROX® *(Pinus roxburghii bark extract)* (PINOROX®) as dietary supplement for enhanced physical performance

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ABSTRACT

Pinorox® is a standardized composition obtained from pine bark extract of Pinus roxburghii, rich source of natural polyphenols - Oligomeric Proanthocyanidins (OPCs) compounds that act as an antioxidant. Pinorox® has been expected to serve as potential natural supplement consumed to enhance the physical endurance in normal healthy or a sport person. Hence, double-blind, randomized, placebo-controlled study was conducted for time period of 90 days to validate the effect of Pinorox® over physical and athletic performances in normal healthy as well as sports subjects. 50 eligible subjects were selected through screening and distributed into placebo and Pinorox® groups. The subjects utilized in the present study i.e., healthy individual and athletes received one of either 200 mg of Pinorox® or experimental control (placebo) for 90 days. Each subject was evaluated for increase in physical or athletic performances by observing changes from baseline in rate of oxygen consumption VO_2 max (endurance) compared to placebo at baseline, assessment of anaerobic power and rate of fatigue by using Wingate test at baseline, changes in assessment values using 1-RM test and muscle grip strength assessment using handheld dynamometer at baseline and during the interval of 90 days. The observations discussed in the present study shows that people consuming Pinorox® displayed significantly advanced performances during exercising or performing given sports activities. Improvement in the VO_2 max values, anaerobic power, rate of fatigue, muscular performance and muscle grip strength was observed in test results and the study did not report any adverse effect. Overall, the study demonstrates that Pinorox® is a safe, fast acting and effective natural dietary or sport supplement for enhancing physical and athletic performances.

1. Introduction

Physical performances are usually recognized as important factor for general fitness (a state of health and wellbeing), prevention of health conditions and specific task oriented or sport-oriented fitness i.e., ability to perform specific skills according to rules of specifically defined sports. Physical performances assess ability of an individual to be able to function efficiently during athletic activities in order to achieve an unanticipated degree of performance through unusual physical exertion [1]. Physical exercises result into a sudden increase in oxidation of nutrients to compensate the elevated energy demand. The oxidative stress in muscle tissue increases during exercise as a result of free radical generation, causing damage to bodily tissues [2]. Antioxidants are essential in protecting these tissues from severe damage caused by the scavenging of reactive oxygen species (ROS) during strenuous exercise. Basically, during high intensity exercises involving muscle mass, there are two physiological needs that compete for metabolic products. First, increased muscle contraction requires increased blood flow accordingly. Second, perfusion pressure needs to be maintained through blood flow [3]. Therefore, physiological systems undergo rapid alterations to support body requirements.

The heart and lungs functioning attains coordination in a manner to match breathing requirements associated with oxygen and carbon dioxide transport in order to fulfil requirements of metabolic processes involved in muscle tissues. With increase in requirements of oxygen during physical exercises, the cardiac output eventually increases oxygen demand during physical activity resulting into a sudden increase in cardiac output and redistribution of blood flow to skeletal muscles [4].

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Maintenance of oxygen supply to muscles, metabolic process of carbon-dioxide exhalation and supply of lactic acid towards renal system are some of the key functions dependent on appropriate blood flow. The process of aerobic energy generation and prevention of anaerobic lactic acid build up is ensured by sufficient oxygenation of muscles [5]. The pattern of blood circulation entails a prominent role in maximum muscular integrity and performance by regulating oxygen intake, blood flow towards skeletal muscles and delivery of oxygen to region of muscular contraction among people involved in high intensity exercises.

During exercise and high intensity muscle activities, contractile performance of skeletal muscles is reduced which causes fatigue. This happens because rate of ATP hydrolysis during energy generation sometimes exceeds rate of re-synthesis resulting into muscular fatigue. Several studies based on human skeletal muscle have shown that during muscular exhaustion, concentration of NADH i.e., electron transporter increases, while concentration of NAD^+ decreases [4,6]. The results imply that rate of NAD^+ reduction to form NADPH is much faster than rate of NAD^+ reoxidation during ATP synthesis. Therefore, compromised electron transfer resulting into increase in NADH levels and decrease in ATP, affects muscle performance and cause fatigue.

It has been known that reduced amount of muscular fatigue has capability of improving physical performance. There are various endogenous defense strategies based on antioxidants that help in coping with oxidative stress. Among these, dietary antioxidants focused to have effect on oxidative stress and muscular damage due to exercise have been researched extensively [7]. The role of Vitamin C as potentially active compound to relieve oxidative stress has been studied. Different adaptations in physical training could be mediated by reactive oxygen species creating physiological effect that could be reduced by Vitamin C. Several studies have stated that consumption of Vitamin C at dosage 1 g or more concentration results into negative impact on sports performance. However, three out of four studies have reported that regular intake of Vitamin C sourced from fruits and vegetables help in controlling oxidative stress, thereby improving physical performance [8]. Thus, a lot of ambiguity exists regarding relevance of Vitamin C in improving physical performance due to absence of clinical studies.

Skeletal muscle is dependent on a number of mitochondrial or sarcoplasmic based enzymes related to copper-zinc dismutase, catalase, glutathione peroxide that help in controlling stress related to oxidation reactions. It has already been known that expression of antioxidant enzymes is often stimulated by high intensity exercises. Therefore, trained individuals may pose greater capacity of antioxidant production as compared to untrained individual [9]. It has been known that performance of individuals involved in strenuous and chronic exercise training gets improved upon taking antioxidant-based supplements [10]. As these supplements provide health and performance benefits to athletes, these supplements are referred as functional foods. One of the possible mechanisms of action associated with these foods include minimizing the impact caused by fatigue that hinders athletic performance.

Another study conducted by Mach et al., based on effect of antioxidant as supplements that can reduce fatigue states that people ingesting antioxidant supplements have shown increase in time of fatigue along with increase in NAD^+ levels [4]. The results are correlated with the hypothesis that antioxidant supplementation reduce oxidative stress, helping in increasing electron transfer efficiency that leads to production of energy (ATP).

According to study conducted by Higgins et al., Vitamin C and Vitamin E as antioxidants hold potential to affect athletic performances. Vitamin E poses effects on two different areas important for physical performance. Vitamin E improves physical performance related to high altitudes as it has shown to decrease RBC deformations but further research is required. Also, ingestion of Vitamin E as acute supplement has shown to improve physical performance during high intensity training along with reduction in intervals of recovery. The study reports possibility of Vitamin E supplementation with or without Vitamin C to be used as antioxidants having adverse effects on adaptations to resistance trainings [11]. The study concludes that effects of these supplements have shown inconsistency in providing muscle mass strength. Therefore, there is need to elucidate role of these supplements in various oxidative states that affects different types of exercises including resistance and endurance training in athletes. Thus, effect of antioxidant supplementation appears to be more personalized depending on fitness level of the athletes. Therefore, more specific clinical studies are required to study effect of antioxidant supplements on physical performance.

It is evident that physical performance could be improved by reducing fatigue. The role of antioxidants in reducing fatigue causing metabolites could be explored for studying role of supplements in enhancing physical performance. The present study deals with Pinorox® which is the standardized extract obtained from the Pine bark of *Pinus roxburghii*. Pinorox® is rich in Oligomeric Proanthocyanidins (OPCs) compounds acts as antioxidant. The study explores importance of Pinorox® as dietary or sport supplement for boosting physical performances in normal healthy individuals as well as athletes.

2. Methods

2.1. Product under study

Pinorox® is the standardized composition obtained from pine bark extract - *Pinus roxburghii*. Bark of *Pinus roxburghii* having moisture content not more than 12% was sorted and cleaned. The dried Pine bark was weighed and pulverized to course powder that is sieved before making the extract. The pulverized powder of Pine bark was charged into the steam jacketed rotary extractor with water in the ratio of 1:5. The steam jacketed rotary extractor was operated for 3 hrs at 80–85 °C to make the mother liquor which was filtered through an on-line filter and then stored in a clean, dry and closed tank. The remaining solid residue of the pine bark was processed again as before by adding water to it in ratio 1:5. The second extract was transferred and stored in a separate clean, dry and closed storage tank.

Further, the residue of the pine bark was processed with 50% methanol in a jacketed rotary extractor. The residue of the pine bark was processed twice a time similarly for 3 hrs at 80–85 °C to make third and fourth extraction that are filtered and stored separately in a clean, dry & closed tank. All the four liquid extracts are combined & hold for 24 hrs at 10 °C for settling insoluble materials following filtration with 200 mesh size nylon cloth to remove insoluble particles. The collected filtered mother liquor was then charged in distillation kettle & distilled under vacuum at 70 °C. The concentration of the extracted aqueous concentrate was standardized up to 25–30% TS (Total solids). De-Fatting of the extract was done at room temperature. For this petroleum ether was added in the aqueous concentrate in the ratio 1:2 and stirred continuously for half an hour to release lipids from the concentrate.

The concentrate was then hold for 2 hrs, for settling to separate aqueous and petroleum ether layers. The aqueous and petroleum ether layer were separated and stored separately in storage tanks. The petroleum ether layer contains low polar impurities that is taken for distillation to recover petroleum ether & remove impurities. The main fraction of Pine bark, aqueous concentrate is further concentrated up to 40% TS (Total Solids) & hold at room temperature for overnight for settling of water insoluble high molecular weight oligomers of procyanidins. The main fraction of Pine bark is then separated into upper water-soluble concentrate of polyphenolic compounds containing phenolic acids, catechin, taxifolin and procyanidins that is further spray dried and lower water-insoluble high molecular weight oligomers of procyanidins which is vacuum dried. Temperature of spray drier inner chamber is fixed at 185 °C–190 °C & outer at 90 °C–105 °C. Both fractions of Pine bark, spray dried and vacuum dried are collected and grinded. The grinded fractions of Pine bark are sieved through 60# (mesh size) and then sterilized in a closed reactor under pressure at a temperature of 105 °C for 1 h. The sterilized pine bark extract was sieved again through 60# (mesh size) & directly packed into fiber drums with double polybags. The Pine Bark

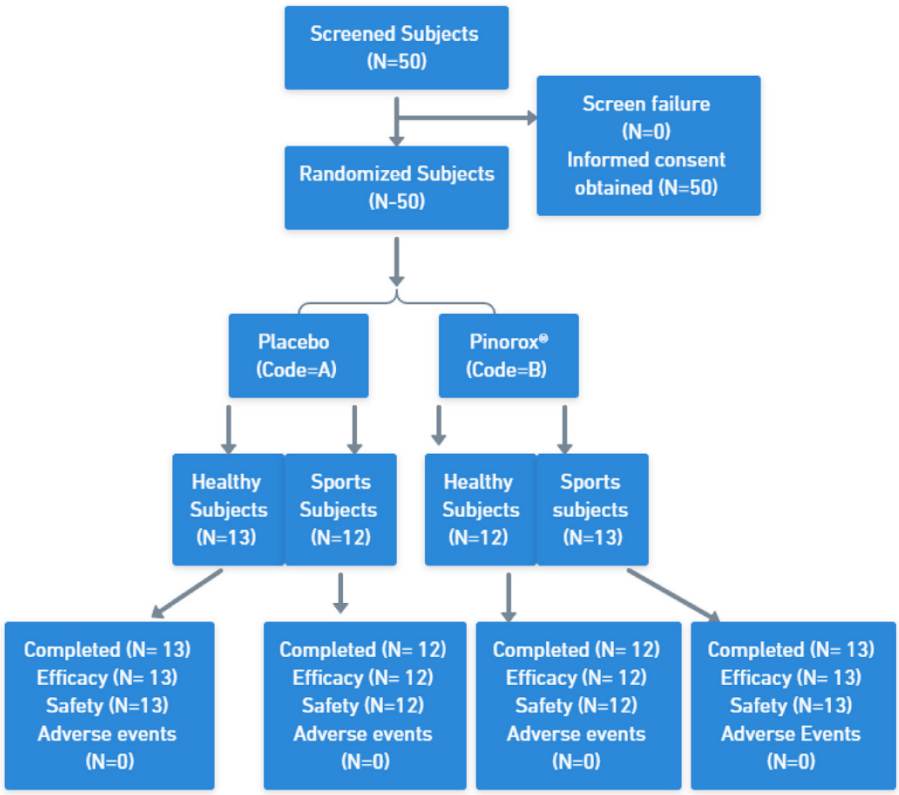

Fig. 1. Schematic flow chart of the events followed during Pinorox® clinical study.

Extract is standardized with >85% Oligomeric Proanthocyanidins content by UV Spectrophotometer. Pine bark extract (**Pinorox®**) sample was extracted with methanol and was measuring the absorbance at 551 nm using methanol as blank against calibration curve using maritime pine extract as standard.

2.2. Characterization of Pinorox®

Each batch of Pinorox® was evaluated for consistency in quality. The test sample, Pinorox® was dissolved in 50% Methanol in the ratio of 0.1:1 and sonicated at 50 °C for 30 min and analyzed using a High Performance Thin-Layer Chromatography (HPTLC) system. The Silica gel 60, HPTLC plates were used as the stationary phase. The sample was applied through a 3 μl auto-injector. The mobile phase consisted of ethyl acetate, formic acid and water in the ratio 10:1:0.6. The run was conducted at 110 °C for 2 mins and the eluted samples were analyzed at 366 nm. The resultant HPTLC chromatogram is provided in Fig. S1 of supplementary data sheet.

For clinical study, Pinorox® was encapsulated in hard gelatin capsules with excipients microcrystalline cellulose powder (MCCP, 8%) and Syloid (2%). Pinorox® is a fine reddish-brown colour powder. 200 mg of Pinorox® capsules or 200 mg of Placebo (Maltodextrin) were given to the subject during clinical study period. To explore the benefit of Pinorox® as a supplement in enhancing the physical and athletic performances in normal healthy and sport subjects, 200 mg of Pinorox® capsules or 200 mg of Placebo (Maltodextrin) were given to the subject during clinical study period.

2.3. Subjects under study

The study was conducted on male and female healthy individuals ranging in age from 18 to 40 years. Male and female healthy subjects (Daily routine with no or little exercises) and sports subjects (Average of more than 3 sessions per week) were included in the clinical study. The consent form regarding approval to support requirements of the study, was obtained from all the participants. The participants agreed to not include any other medication regime, including any dietary or herbal supplements and avoid the intake of antioxidant rich food while being involved in this study. Participants were informed to avoid exercising at least 48 hrs prior to the clinical check-up along with fasting period of 2 hrs before the checkup. Participants having clinically significant medical history were excluded from the study. The subjects with or prior history or presence of clinically significant cardiovascular, pulmonary, hepatic, renal, haematological, gastrointestinal, endocrine, immunologic, dermatologic, musculoskeletal, neurological or psychiatric disease as well as subjects has any orthopaedic problem(s) or history of musculoskeletal injuries which make resistance weight training contraindicated, were excluded from the study.

2.4. Research design

The placebo-controlled trial was conducted at one site for 3 months duration. The protocol used in the study has been successfully approved by the Institutional Ethics Committee Rajalakshmi Hospital, Bangalore, Karnataka, India (Clinical Trial Registration No. CTRI/2019/03/018174). A 90-days, randomized and double-blind study was executed to examine effect of Pinorox® for enhancing the physical and athletic performances in normal and sports subjects. Approximately, 50 eligible subjects sorted through the screening process were involved in the study. The people involved in the study were subjected to one of the two supplements - either 200 mg ($n = 25$) of Pinorox® or placebo ($n = 25$) daily for 90 days. Each person was evaluated for increase in physical performances by observing changes in VO_2 max i.e., maximal oxygen intake (endurance) compared to placebo at baseline within time intervals of 30, 60 and 90 days respectively. The assessment of anaerobic power and rate of fatigue was evaluated by conducting a cycle test of anaerobic leg power i.e., Wingate test at baseline during time intervals of 30, 60 and 90 days respectively. In order to assess strength capacity of subjects, changes

Table 1
Formulae used for calculating different performance indices.

Performance Index	Output	Formula
Peak Power Output (PP)	Distance - evaluated by number of revolutions in the first 5 sec x distance per revolution	PP = *f* x *d* ÷ 0.0833, Where *f* is force and *d* is distance
Relative Peak Power Output (RPP)	Dependent on peak power (PP) and body mass	RPP = PP ÷ Body mass (kg)
Anaerobic Fatigue (AF)	percentage decline in power output	AF = ((Highest 5 sec PP - Lowest 5 s PP) ÷ (Highest 5 sec PP)) x 100
Anaerobic Capacity (AC)	Total work accomplished in 30 sec	AC = Sum of each 5 sec PP

in assessment values using one-repetition maximum (1-RM) test at baseline during interval of 90 days was conducted. The muscle grip strength was analyzed using handheld dynamometer at baseline and end of 90th day.

2.5. Randomization and treatment

A total of 50 subjects were selected and recruited for the study. As shown in Fig. 1, each subject was randomly assigned into the Placebo and Pinorox® group, respectively. The codes representing randomization of subjects were kept confidential by the clinical trial pharmacist and statistician. Each subject provided the basic details (Demographic details, medical history etc.) in the questionnaire during initial check and during follow up evaluation on 30th, 60th and 90th day respectively.

2.6. Assessment of physical performances

2.6.1. Aerobic performances

Aerobic performance involves physical exercises of low to high intensity that depends primarily on the aerobic energy-generating process. The subjects were asked to participate in the Bruce protocol treadmill test in order to get an idea about their endurance at baseline, 30th, 60th and 90th day of study duration, respectively. Maximal oxygen uptake (VO_2 max) was evaluated in order to check maximum amount of oxygen that an individual require during intense or maximal exercise. In order to evaluate aerobic performance [12]. The Bruce treadmill test was implemented to estimate VO_2 max using specific formulae for men and women to analyze whether the subject is able to exercise on the treadmill.

For men, from the total walk/run time an estimate of the athlete's VO_2 max was calculated as shown in equation (1).

$$VO_2\ max = 14.8 - (1.379 \times T) + (0.451 \times T^2) - (0.012 \times T^3) \quad (1)$$

For women, the total walk per unit run time as an estimate of the athlete's VO_2 max was calculated as shown in equation (2)

$$VO_2\ max = (4.38 \times T) - 3.9; \quad (2)$$

Where, "T" is the total time of the test expressed in minutes.

2.6.2. Anaerobic performances

In order to study anaerobic performances of the subjects, several performance indices were evaluated which include peak power (PP) i.e., highest value of mechanical power resulting from the test where the average power over any 5 seconds period, usually the first 5 sec, mean anaerobic power (MAP) i.e., the average power maintained throughout the six segments of 5 s [13], anaerobic fatigue or fatigue index (FI) i.e., the amount of the decline in power during the test expressed as a percentage of peak power and anaerobic capacity recorded over the entire 30 sec [14] and anaerobic capacity (AC) i.e., total amount of physical work accomplished within 30 sec. The indices were calculated according to formula mentioned in Table 1.

A. Wingate Anaerobic Test (WANT)

The Wingate test also known as the Wingate Anaerobic Test (WANT) evaluates the anaerobic power of the lower body. The anaerobic power basically contributes in developing strength, speed, power and muscle mass especially in non-endurance sports. During non-endurance sports, the anaerobic power promotes strength, speed and builds muscle mass. The muscle and energy generation system that eventually develops during course of anaerobic exercise results into greater performance in short duration such as high intensity activities [15]. Overall, the anaerobic capacity is the total amount of energy from the anaerobic (without oxygen) energy systems that is the combined amount of output for the ATP, phosphocreatine and lactic acid systems [16]. The Wingate test helps in evaluating values of indices explained in Table 1.

B. One-repetition maximum (1-RM) Bench Press Test

In order to determine anaerobic power of subjects during physical activities, strength capacity was evaluated by 1-RM bench press test. One-repetition maximum (1-RM) represents the maximum value of weight that is a person is capable of lifting in one repetition. It may also be considered as one maximal contraction resulting into maximum amount of force [17]. Briefly, post warm-up, achievable amount of weight was chosen followed by rest period of at least several minutes. Subsequently, the weight was increased and exercise was performed again. The subjects chose subsequent weights until they can only repeat one full and correct lift of the weight. The maximum weight lifted was recorded as well as score was standardized in proportionality with the subjects' bodyweight.

C. Muscle grip strength using handheld dynamometer:

The test was conducted to measure maximum isometric hand strength and forearm muscle strength. The dynamometer was held by the test subject while arm was kept at right angle and elbow in contact with side of the body. The dynamometer handle was adjusted if required in order to ensure that the base is rested on palm heel, while the handle is supposed to rest on middle of the four fingers. When ready, the subject was asked to apply pressure on the dynamometer with maximum isometric effort, maintained constant for about 5 sec refraining ensuring no other body movement. Several trials for each hand were conducted and the best result corresponding to each hand was recorded, while between each effort recovery period was maintained as 15 sec [18]. Apart from aerobic and anaerobic performance assessment, hematological and biochemical parameters were evaluated at baseline and day 90 in both the groups, Pinorox® and placebo (data not shown).

2.7. Statistical analysis

Detailed statistical analysis was performed using SAS® software for windows, version 9.1 at 5% level of significance ($\alpha = 0.05$), to examine functional effectiveness of Pinorox® as compared to the placebo group in terms of improvement in physical and athletic performances at baseline during 30, 60 and 90 days of treatment, respectively. The differences in results were assessed using paired *t*-test and the results was analyzed by independent *t*-test.

3. Results and discussion

3.1. Demographic characteristics

According to data obtained from 50 subjects that were selected and recruited for the study, which were assigned into Placebo and Pinorox® group, the arithmetic mean of age of the subjects' age was recorded as 30.08 years and 30.64 years in the Pinorox® and placebo groups respectively. The mean body weight of the subjects was 64.14 kg and

Table 2
Aerobic performance results in normal healthy and sports subjects. VO_2 max values obtained using Bruce protocol. (Values are in Mean ± SD (Standard Deviation), Independent-t test, **p value < 0.05*).

Treatment		VO_2 max (mL/kg min^{-1})			
		Baseline	Day 30	Day 60	Day 90
Pinorox®	Mean (n = 25)	36.66	43.00	47.36	50.61
	SD	7.70	7.07	6.90	5.80
Placebo	Mean (n = 25)	35.63	35.37	35.6	34.87
	SD	9.05	9.11	8.17	8.36
p-Value (Independent *t*-test)		0.43238	0.00179*	<0.00001*	<0.00001*

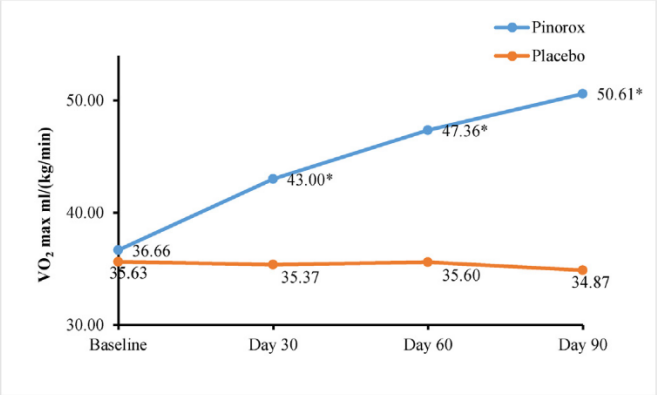

Fig. 2. Change in aerobic performance of normal healthy and sports subjects. (VO_2 max values obtained using Bruce protocol; Independent *t*-test **p value < 0.05*).

65.72 kg in the Pinorox® and placebo groups, respectively, while mean height of the subjects was 167.88 cm and 168.72 cm in the Pinorox® and placebo groups, respectively. The mean BMI of the subjects was 22.77 kg/m^2 and 23.05 kg/m^2 in the Pinorox® and placebo groups, respectively.

3.2. Aerobic performance in normal healthy and sports subjects

According to results of aerobic performance tests, there was improvement in the VO_2 max values (mL/kg/min) in the Pinorox® group when compared to placebo group and the differences were observed to be statistically significant *(*p<0.05)*. The VO_2 max values (mL/kg/min) of the Pinorox® and placebo group are presented in Table 2 & Fig. 2. In Pinorox® group VO_2 max values were improved consistently from 30^{th} day to 60^{th} day of the study, while no significant improvement was observed in the placebo group. Thus, the aerobic fitness was found to be significantly improved in healthy as well as in sports subjects taking Pinorox® daily.

3.3. Anaerobic performances in normal healthy and sports subjects

Based on results of Wingate Test, significant improvement in power output value (in kg*m/min & Watts), relative power output value (in W/Kg) and anaerobic capacity in test group (in kg*m/min & Watts) was observed in the Pinorox® group in comparison with experimental control (Placebo) group at baseline, 30^{th}, 60^{th} and 90^{th} day, respectively as shown in Figs. 3 and 4. Whereas, anaerobic fatigue was found to be reduced in Pinorox® treated subjects (Fig. 3d). Anaerobic performances help in providing better strength, speed and power when a person performs non-endurance sports. The results imply that intake of Pinorox® helps in reducing overall anaerobic fatigue, due to which overall anaerobic capacity was improved in treated subjects. Thus, the study indicates that indicates that Pinorox® may help to improve physical performances during endurance exercises both in normal healthy and sport subjects.

Further, one-repetition maximum test was conducted to evaluate body strength and muscular capacity of subjects on non-laboratory equipment. One-repetition maximum (1-RM) value represents physical

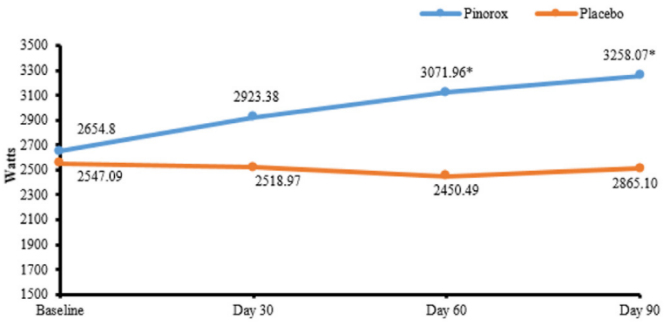

Fig. 4. Anaerobic Capacity according to Wingate test conducted on normal healthy and sports subjects in Pinorox® and Placebo groups. (Independent t-test, **p < 0.05*).

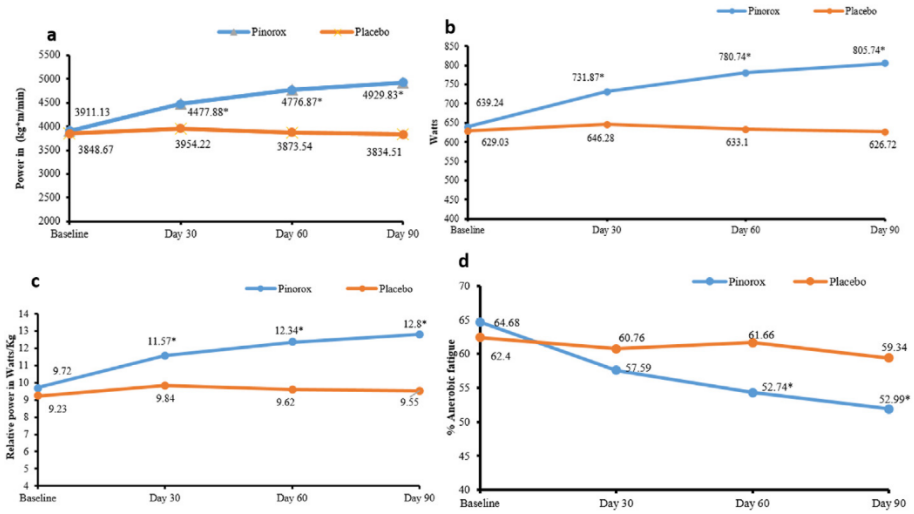

Fig. 3. Anaerobic Performances in Wingate test conducted on normal healthy and sports subjects in Pinorox® and Placebo groups. a) Peak power comparison; b) Peak power comparison in watts; c) Relative power comparison; d) Anaerobic Fatigue comparison (Independent t-test, **p < 0.05*).

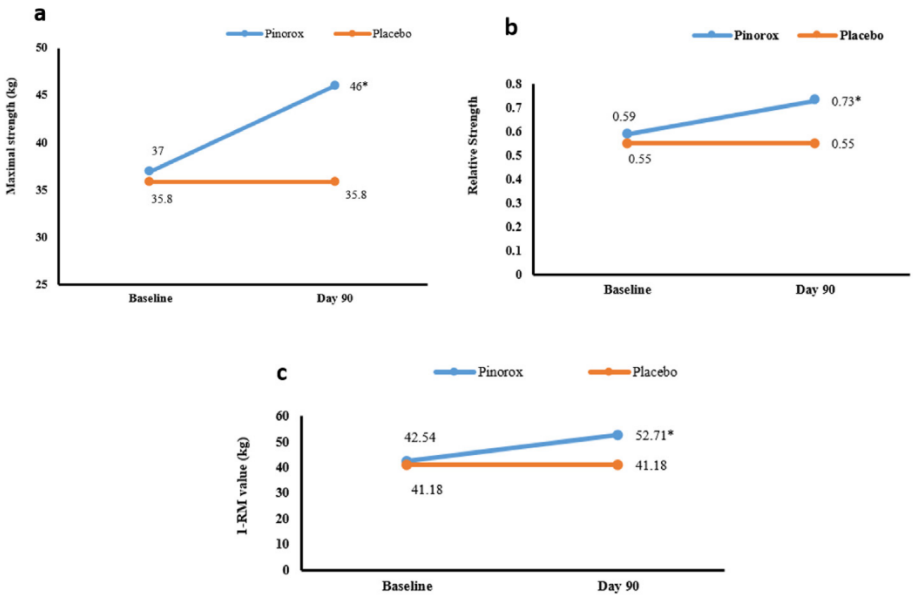

Fig. 5. One-repetition maximum (1-RM) test between Pinorox® and Placebo groups. a) Maximal Strength comparison, b) Relative Strength comparison and c) One-repetition maximum (1-RM) value comparison (Independent *t*-test, **p value* < 0.05).

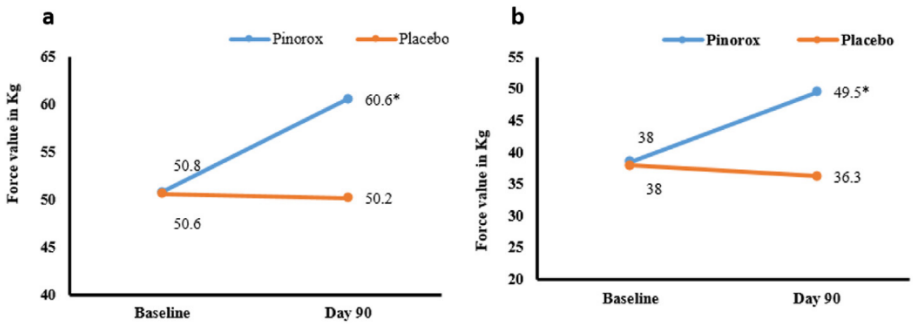

Fig. 6. a) Muscle grip strength value using handheld dynamometer between Pinorox® and Placebo groups in normal healthy and sports subjects. a) Muscle grip strength of Left hand and b) Muscle grip strength of Right hand (*Independent t-test,* *p value < *0.05)*.

ability of the person to lift maximum amount of weight in one repetition. As seen in Fig. 5, there was increase in lifting mass in Pinorox® group when compared to Placebo group. The maximal strength was found to be increased from 37 kg to 46 kg within time period of 90 days. The differences were statistically significant between the groups. The relative strength was improved, which resulted into improved 1-RM values. The results imply that supplementation of Pinorox® has shown positive effect on muscle strength of healthy as well as sports individuals.

Furthermore, strength of muscular grip formed by the subjects was analyzed to examine strength of hand grip using galvanometer in order to measure the maximum isometric hand strength and forearm muscle strength. As seen in Fig. 6, The Right-hand value (RH-value) and Left-hand value (LH-value) of Muscle grip strength was increased in Pinorox® group when it's compared to placebo group at baseline and day 90, respectively. The results show that Pinorox® is capable of positively affecting the isometric strength of hands and forearm muscles.

Overall, the results indicate that Pinorox® may help to improve physical performances during endurance exercises both in normal healthy and sport subjects. An outstanding result of the study is the fact that Pinorox® group achieved better results compared to control group. Normally, a more energy and muscle strength intense physical activity produces more amount of oxidative stress. Pinorox® group outperformed the control group may be because Pinorox® subjects were better protected while performing physical activities against free radicals than the control group. It is uncertain whether this elimination of free radicals during exercise enables the Pinorox® group to a better performance. Pinorox® may help in complete protection against oxidative stress inhibit the circulation of free radicals and we measured better results with respect to physical performances under Pinorox®.

The combination of tests employed in the present study may not be complete or ideal to assess the protection against oxidative stress, but it is an important expression of overall increase in physical performances & fitness which is considered on the basis of test results. Hence, the present study is mainly focused on proving that Pinorox® - a supplement may have a positive effect on endurance performances in normal healthy as well as sport subjects. The study provides significant evidence that significant physical performance improvement was observed and hence, Pinorox® holds potential to be used as dietary supplement for enhancing physical performances during endurance exercises.

4. Conclusion

The present study supports the potential efficacy of Pinorox® as a dietary or sport supplement. In a clinical trial study, Pinorox® group has been found to be effective for boosting aerobic and anaerobic performances and general well-being in healthy and sports subjects. Pinorox® supplementation displays improved endurance, muscle power and overall strength over a period of 90 days. The study also suggests that

supplementation of Pinorox® with complete hydration and nutritional diet may improve physical performances or activities and endurance among normal healthy subject and athletes while performing high stress and heavy exercises or any other physical activites. Considering Pinorox® ability to enhance endurance while performing physical activites, the study opens potential scope of elucidating it's mechanism of action on human body. Although Pinorox® is a rich source of antioxidant and it is expected to improve the physical performances by maintaining balance of antioxidants and energy generation, further research could be performed on similar grounds. As Pinorox® is expected to function as antioxidant, molecular mechanism of action could be explored in future.

Declaration of competing interest

The authors declare that the authors have no conflict of interest among them.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jics.2021.100325.

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