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Original Article

The effect of beach volleyball training on running economy and VO2max of indoor volleyball players

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Abstract:
The purpose of this study was to investigate the effect of systematic beach volleyball training and competition on running economy (RE) and VO_{2max} of indoor volleyball players. Thus, the participants underwent two measurements. The first measurement (PRE) occurred before the players begin systematic beach volleyball training, just after the end of indoor volleyball season. The second measurement (POST) occurred after the final tournament of the beach volleyball season, twelve weeks after the first measurement. All of them underwent anthropometric measurements, body fat assessment and performed running on treadmill at speeds of 8, 10 and 12 km·h-1 for three minutes at each level. Parameters such as heart rate (HR), VO_2 in absolute and relative values, respiratory exchange ratio (RER) and minute ventilation (VE) were recorded. Moreover, VO_{2max} was also tested. Body mass and fat were significantly decreased after the beach volleyball period. HR decreased significantly ($p<.01$) at 8, 12 and 10 $km{\cdot}h^{-1}$ and VO_2 differ significantly, with a decrease in 8 ($p<.05$) 10 ($p<.01$) and 12 $km{\cdot}h^{-1}$ ($p<.001$) in both absolute ($l{\cdot}min^{-1}$) and relative ($ml{\cdot}kg^{-1}{\cdot}min^{-1}$) values, showing an improvement of RE. RER decreased significantly at the speeds of 10 ($p<.05$) and 12 km·h-1 ($p<.01$), whereas VE recorded a significant difference in 12 $km{\cdot}h^{-1}$ ($p<.001$). Additionally, the results indicate a significant increase in VO_{2max} ($p<.01$) both in absolute ($l{\cdot}min^{-1}$) and relative ($ml{\cdot}kg^{-1}{\cdot}min^{-1}$) values. Conclusively, it seems that systematic beach volleyball training leads to an improvement of RE and VO_{2max} of the amateur indoor volleyball players. These findings indicate that the improvements caused by beach volleyball training can be considerably effective in the performance of the athletes throughout the total duration of a volleyball game.
Key words: Beach volleyball training, amateur indoor volleyball players, running economy, VO_{2max}, body fat.

Introduction

Beach volleyball is a very demanding sport which is played outdoors usually under difficult conditions such as high temperature, wind even rain. The number of matches played per day (2 up to 5) during the weekend tournament and the fact that both players touch the ball in almost every phase of the game are factors of extra difficulty. Furthermore, volleyball performance (jumps, dives and other sport-specific drills) on sand makes beach volleyball more demanding than indoor volleyball.

All sports require utilization of the high energy phosphates, but volleyball rely almost exclusively on this means for energy transfer. Volleyball requires a brief but maximal effort during performance and thus, a volleyball player needs an increased capacity to generate energy rapidly from stored high energy phosphates. For sustained energy and for recovery from a prior brief all-out effort, additional energy must be generated for ATP replenishment. (McArdle et al., 1996). Whilst ATP phosphate system is mostly required especially in the crucial phases of a match, due to the long duration of a volleyball game (more than 60 min) the aerobic energy demand is increased. Thus, aerobic capacity performs as a good back up for the renewal of energy phosphates and energy production during the small pauses between the match phases (e.g. when the athlete doesn't have direct involvement in the match phase, etc.) (Åstrand & Rodalh 1986). Therefore it seems likely that a volleyball athlete needs an increased aerobic capacity for better and faster loading of the energy phosphagen storages in order to keep performing better during the whole duration of the game.

It is very common for indoor volleyball players to perform beach volleyball training during summer time and participate in official tournaments in order to keep in good physique, since 85 rallies occur in 25-42 minutes of play (Giatsis, 2003; Giatsis & Zetou 2003). An intriguing question that rises is what benefits they get from a demanding "relative" sport such as beach volleyball in terms of aerobic capacity (Running Economy and VO_{2max}).

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In the literature, VO_{2max} has been regarded as a good predictor of endurance performance in untrained subjects. However, other variables such as maximal aerobic velocity and running economy (RE) have been cited as better (Conley & Krahenbuhl, 1980; Morgan et al., 1989; Paavolainen et al., 1999). RE is typically defined as the energy demand for a given velocity of submaximal running, and it is determined by measuring the steady state consumption of oxygen (VO_2) (Saunders et al., 2004). Many factors have been associated with RE, including temperature, heart rate, ventilation, VO_{2max}, age, gender, body mass, muscle fiber type distribution, and other biomechanical variables (Morgan et al., 1989; Daniels & Daniels, 1992; Morgan & Craib, 1992; Pate et al., 1989; Saunders et al., 2004).

A common training method to improve RE is slow long distance running (Sjodin & Svedenhag, 1985), but some other types of running training such as high intensive interval training seem to be also effective on RE (Conley& Krahenbuhl, 1981; Daniels, 1998).

Moreover, there are some other methods of anaerobic training which interestingly seemed to be effective on RE. Heavy resistance strength training has improved the endurance performance of previously untrained subjects (Hickson et al. 1988; McCarthy et al. 1995) or RE (Johnston et al. 1997) without changes in $\dot{V}O_{2max}$, suggesting that neuromuscular characteristics may also be important for endurance performance. Additionally, another type of anaerobic training such as plyometric training seem to improve the running economy of endurance runners (Spurrs, et al. 2003) and intermediate (not high level) distance runners (Turner, et al. 2003).

Regarding training and performance on sand, few studies (Zamparo et al. 1992; Lejeune et al. 1998; Pinnington & Dawson 2001a and 2001b) have investigated the energetics of running on sand, providing an insight into the training stimulus that may accrue for athletes who incorporate sand running into their training regimes. Zamparo et al. (1992) reported that at running speeds ranging between 7-14 $km{\cdot}h^{-1}$ the energy cost (EC) of sand running was approximately 24% greater than firm ground values. Lejeune et al. (1998) reported that the net aerobic EC of running on an artificial circular sand track was approximately 1.6 times greater than running on a firm surface. Pinnington and Dawson 2001a, found the net total EC of recreational runners at 8, 11 and 14 $km{\cdot}h^{-1}$ to be approximately 1.5 - 1.6 times the sand to grass EC. This data suggests that running on sand potentially provides a low impact and high EC training stimulus (Pinnington and Dawson 2001a). However, these previous studies haven't monitored the effect of short-term sand training in $\dot{V}O_{2max}$ and RE. To our knowledge, there's no research in the literature studying the effects of systematic beach volleyball training and competition on physiological parameters of indoor volleyball players.

Method

Participants

Eleven (n=11) male amateur indoor volleyball players age 26.5 ±3.3 years, training experience 13.2 ±3.2 years, height 187.3 ±4.9 cm body mass 84.6 ±6.2 were volunteered to participate in this study. All of them had completed an indoor volleyball season with their clubs and were going to conduct systematic beach volleyball training in order to participate in official tournaments of the Hellenic volleyball federation during summer time. Thus, the subjects underwent two measurements. The first measurement (PRE) occurred before the players begin systematic beach volleyball training, just after the end of indoor volleyball season. The second measurement (POST) occurred after the final tournament of the beach volleyball season, twelve weeks after the first measurement. All participants were fully informed of the testing as well as the associated risks and given written consent forms prior every measurement of the study.

Procedures

Beach volleyball training and tournaments

Beach volleyball training was not manipulated in that study and subjects went through the summer following their own, or their coaches' training routine. They were training on the sand performing specific beach volleyball drills, exercises, tactics or friendly matches 4-6 times per week, duration 2.00- 2.30 hours each session, for a period of 12 weeks. During weekends they participated in official beach volleyball tournaments of the Hellenic volleyball federation. The number of tournaments reached an average of 7.67±1.72 per subject.

Running economy and cardiorespiratory endurance

All participants were tested before (PRE) and after (POST) 12 weeks of systematic beach volleyball training and competition. Heart rate (HR), running economy (RE) in absolute and relative values, $\dot{V}O_{2max,}$ respiratory exchange ratio (RER) and minute ventilation (VE) were tested on a treadmill. Before the initialization of the test, anthropometric characteristics as height, body mass and fat were recorded. Each measurement on the treadmill started when the subjects had completed a 5 min warm-up and 8 min stretching. Commencing at velocity of 8 $km{\cdot}h^{-1}$ and 0% angle the participants ran for 3 min. Then, without a pause the speed increased to 10 $km{\cdot}h^{-1}$ with a steady angle of 0% for 3 min. After the 3rd min an increase to 12 $km{\cdot}h^{-1}$ occurred with a concurrent increase of angle by 2% for 3 more min. The test continued by gradually increasing speed every minute with the angle remain steady at 2% until exhaustion, were the subject could no longer maintain the treadmill velocity. Since running economy is defined as the steady state VO_2 for a given running velocity (Morgan et al., 1989), the running economy in this study was determined by averaging the VO_2 values for the last minute at velocities of 8, 10 and 12 $km \cdot h^{-1}$. A Jaeger open spirometry system (Oxycon-Pro, Jaeger Wurzburg, Germany) associated with a treadmill (HP Cosmos, Pulsar, Nussdorf-Traustein, Germany) and a telemetric heart rate monitor (Polar, Kempele, Finland) was used for breath by breath evaluation during the test. The room temperature was 20-22^{o} C and the relative humidity was approximately 50%. The protocol of this study was in accordance with the guidelines of the Ethical Committee of Aristotle University of Thessaloniki and the revised Declaration of Helsinki. All participants gave their written consent of participating in the study.

Body fat measurement

For the determination of body fat, a skinfold thickness instrument (Lafayette Instrument Co., Indiana USA) was used. The skinfold thickness measurements conducted were: diceps brachii (s1), triceps brachii (s2), suprailiac (s3) and subscupular (s4) using a specific caliper (Dr Lange, Santa Cruz, California). Body density was determined according to Durning & Rahaman (1967), $D = 1.161 – 0.0632\log(s_1 + s_2 + s_3 + s_4)$

Body fat was calculated according to Siri's equation (Siri; 1956) $F(\%) = [(4.95 / D) – 4.5] \times 100$.

Statistics

Data are presented as mean and standard deviations. The statistical significance of the differences between the pre and post beach volleyball training results was determined using the non-parametric Wilcoxon signed rank test (exact). *P* values below 0.05 were considered statistically significant.

Results

The possible effect of beach volleyball training on running economy of indoor volleyball players was analysed statistically using the variables of heart rate, VO_2 in absolute and relative values, respiratory exchange ratio and ventilation. In addition, VO_{2max} was recorded in absolute and relative values also. In parallel, body mass and fat changes have been recorded. Twelve weeks after systematic beach volleyball training and competition body mass and fat were significantly decreased (p<.001) (table1).

Table 1. Body mass and fat.

Body mass (kg)		Body Fat (%)	
Pre	Post	Pre	Post
84.60±6.21	82.31±6.04***	19.38±2.92	16.79±2.63***

***p< .001

A significant reduction (p<.01) in HR was recorded at 8, 10 and 12 $km \cdot h^{-1}$. In addition, VO_2 differ significantly after beach volleyball period, with a decrease in 8 (p<.05) 10 (p<.01) and 12 $km \cdot h^{-1}$ (p<.001) in both absolute ($l \cdot min^{-1}$) and relative ($ml \cdot kg^{-1} \cdot min^{-1}$) values, showing an improvement of RE. Other parameters of RE such as RER decreased significantly at the speeds of 10 (p<.05) and 12 $km \cdot h^{-1}$ (p<.01), whereas VE recorded a significant difference in 12 $km \cdot h^{-1}$ (p<.001) (table2). Moreover, the results indicate a significant increase in a VO_{2max} (p<.01) in both absolute ($l \cdot min^{-1}$) and relative ($ml \cdot kg^{-1} \cdot min^{-1}$) values (fig1, fig2).

Table 2. Results.

	8 $km \cdot h^{-1}$		10 $km \cdot h^{-1}$		12 $km \cdot h^{-1}$	
	Pre	Post	Pre	Post	Pre	Post
Heart rate	136.54±11.58	129.09±11.41**	153.72±12.12	147.71±10.46**	167.81±11.31	161.00±11.26**
VO2 (l/kg)	2.43±0.27	2.33±0.28*	2.94±0.32	2.85±0.30**	3.47±0.44	3.32±0.36***
VO2(ml/kg/min)	29.18±1.79	28.12±1.94*	35.45±2.27	34.48±2.28**	41.71±3.15	40.09±2.77***
RER	0.84±0.06	0.80±0.03	0.92±0.05	0.87±0.05*	0.99±0.07	0.92±0.06**
VE (l/min)	53.00±6.79	50.09±8.64	69.72±9.23	65.45±9.97	88.81±15.72	84.09±14.64***

* p< .05 **p< .01 ***p< .001

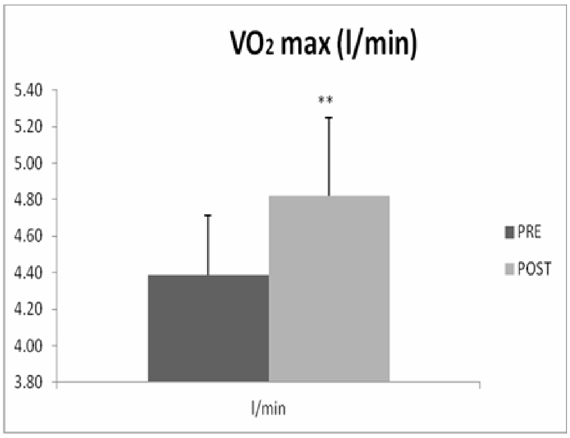

Fig. 1. VO_{2max} ($l{\cdot}min^{-1}$)

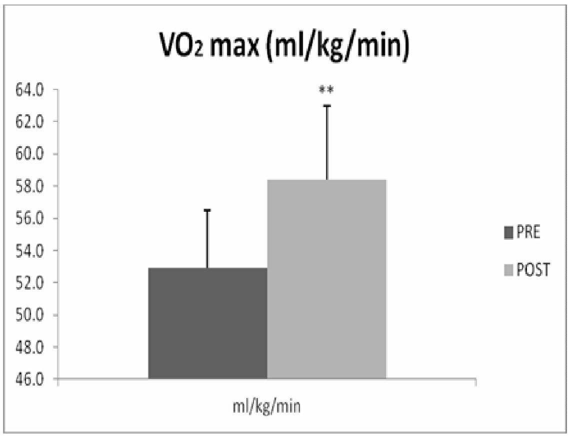

Fig. 2. VO_{2max} ($ml{\cdot}kg^{-1}{\cdot}min^{-1}$)

Discussion

The rationale of this study was based on the hypothesis that since the energy cost (EC) of walking or running on sand is proven bigger than the firm surface, beach volleyball may have increased aerobic demands than indoor volleyball. Hence, beach volleyball training and competition may possibly cause some aerobic adaptations in indoor volleyball players.

Many athletes and coaches have previously used sand training as a successful adjunct to firm surface training regimes (Berger, 1980; Wischnia, 1982; Oviatt and Hemba, 1991). Studies by Zamparo et al. (1992), Lejeune et al. (1998) and Pinnington and Dawson, (2001a and b), have quantified the EC of running on sand and found it to range between 1.2 to 1.6 times firm surface values at comparable running speeds. Pinnington and Dawson (2001b), revealed that iron men athletes ran at steady state on soft dry beach sand at 8 and 11 $km{\cdot}h^{-1}$ the aerobic EC was approximately 1.4 times greater than when running on grass at comparable speeds. Zamparo et al. (1992) reported that net total EC of running on sand was 1.1-1.4 times greater than running on a firm surface at running speeds ranging between 7 and 14 $km{\cdot}h^{-1}$. Lejeune et al. (1998) measured the aerobic EC of running on an artificial circular sand track and reported that the EC of sand running increased 1.6 fold relative to running on a firm surface. This value agrees more closely with the aerobic EC reported by Pinnington and Dawson (2001a) for recreational runners, who ran on soft dry beach sand compared to running on grass, but is greater than the value (1.38) found for the iron men (Pinnington and Dawson 2001b). It is possible that specific training responses associated with habitual sand running, elicited by the iron men when running on sand, may have resulted in a reduced submaximal VO_2 at comparable running speeds compared to non-habituated sand runners. These investigations provide some insight into the physiological training stimulus that may accrue by running on sand, compared with a firm surface.

Our study revealed that VO_2 consumption of indoor volleyball players was significantly reduced after a beach volleyball season (12 weeks) in 8, 10, and 12 $km{\cdot}h^{-1}$ ($p<.05$, $p<.01$, $p<.001$ respectively) running on treadmill. Additionally, there was a significant reduction of HR in all speeds and difference in RER. These results suggest that beach volleyball training and competition evoked specific training adaptations that resulted an improved RE compared to the indoor volleyball effect. Furthermore, the improvement in VO_{2max} seems to confirm other studies' evidence suggesting that VO_{2max} is an important determinant of the O_2 cost of running and RE (Bransford & Howley 1977; Morgan et al. 1989; Morgan & Craib, 1992; Bernard et al. 1998). However, wide variations in RE have also been observed within groups of trained runners with similar $VO_{2\ max}$ values (Conley and Krahenbuhl 1980; Morgan et al. 1992; Bernard et al. 1998). No differences in RE have also been reported between trained and untrained subjects (Dolgener 1982). The lack of agreement in the literature concerning the effects of physical training or $VO_{2\ max}$ on RE suggests that the differences in $VO_{2\ max}$ pre and post beach volleyball season used for comparison in the present study may limit the inferences that can be made from the data.

In the light of previous studies (Pinnington and Dawson 2001ab, Lejeune et al. (1998) Zamparo et al. (1992) which given evidence of increased EC in sand, we could claim that our results seem to be an extension of their theory. Since moving on sand demands increased EC, systematic training and competition on sand could result an improvement in RE and an increase in $VO_{2\ max}$.

We assume that the specific physiological adaptations responsible for the improved RE and $VO_{2\ max}$ of volleyball players after beach volleyball training and competition, include differences in muscle oxidative capacity, anaerobic threshold and oxygen deficit temperature, heart rate, ventilation, RER, VO_{2max}, body mass, and other biomechanical variables(Morgan et al., 1989; Daniels & Daniels, 1992; Morgan & Craib, 1992; Pate et al., 1989; Saunders et al., 2004). Additionally, another parameter that could possibly have influenced RE is the adaptation and better response of the thermoleguratory mechanisms in high temperature, since plenty of matches occur in any time of the day, and during summertime in Greece temperature often reaches 35-40^{o}C. A positive association between body temperature and VO_2 constant-load exercise and submaximal exercise performed under hyperthermic conditions has been documented (MacDougal et al., 1974; Saltin & Stenberg, 1964). It has been suggested that the temperature related rise in VO_2 is linked to added peripheral blood flow and sweating demands, increased ventilatory rate, and decrease in the efficiency of oxidative phosphorylation (Brooks et al., 1970; Brooks et al., 1971; Gaesser & Brooks., 1984).

Conclusions

It seems likely that 12 weeks of systematic beach volleyball training and competition led to additional benefits in the physical adaptations of indoor volleyball players. The improved RE and VO_{2max}, can be considerably effective for the athletes in order to sustain a high performance throughout the total duration of a volleyball game.

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