Original Article

Influence of plyometric jump training on the physiological changes of male handball players

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ABSTRACT

Running economy and velocity at maximal oxygen uptake are considered the most substantial physiological performance indicators in team sports. plyometric training are important techniques that enhance the neuromuscular functioning in athletes. The aim of the present study is to investigates the change in maximal oxygen uptake (VO_{2max}) and running economy (RE). 16 male participants aged 21 years old. Participants underwent pre- and post-intervention tests including running economy, VO_{2max} within 48 h before and after the training protocol. Statistically significant differences were seen in running economy and V_{O2max} after training (p < .01). The current study suggested that plyometric training for 12 weeks can improve running economy and VO_{2max}.

Keywords: Plyometric, Running economy, VO_{2max}.

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INTRODUCTION

Plyometric training involves high-velocity movements performed in rapid succession where muscle lengthening contraction is rapidly followed by shortening contraction. Among the types of plyometric training, jump training is the most common, it includes skips bounding, sets of jumps, and hops performed at a high speed and maximal effort (Sáez de Villarreal et al., 2012). Explosive speed training is used to increase sprint speed and consists of maximal velocity running efforts for 15 seconds or less and full recovery periods among repetitions. Moreover, explosive speed training can improve muscle conduction velocity, and is an indicator of neuromuscular performance related to sprint speed (Ross et al., 2001).

It is noteworthy that jumps must be performed after a high-intensity run like throwing a fast strike in the air during handball exercises. Consequently, the ability to repeat these explosive sequences are considered an essential indicator in team sports (Sheppard et al., 2007; Buchheit et al., 2010). Typically, players in team sports, such as basketball and handball, have to repeatedly practice sequences of short explosive efforts like short sprints(15-25 m), then should make repeated changes of direction followed by maximal jumps (Abdelkrim et al., 2007).

The significant responses to repeated jumps and sprints reflected essential considerations about training prescriptions of team sports as they may lead to central and peripheral improvement (examples include preservation of neuromuscular performance, muscle buffer capacity, and PCR recovery, O_2 extraction and utilization, and inter muscle coordination patterns) (Billaut et al., 2005; Edge et al., 2006; Stone et al., 2009).

With regard to endurance running, it is determined by two factors: running economy and maximal oxygen uptake (VO_{2max}) (Joyner, 1991; Prampero, 2008). Both factors can be defined as the velocity at VO_{2max} (vVO_{2max}), which account for about ~ 90% of inter-individual variance in performance over 16.1 km. In order to achieve success in endurance competitions, exceptional values of both factors should be obtained, note that endurance runners try to improve both parameters training to maximize their performance (McLaughlin et al., 2010).

In fact, the impact of performing plyometric training for longer than 12 weeks for handball players is still unknown. Therefore the present study to investigates the change in VO_{2max} and running economy among subjects responding to plyometric training.

MATERIAL AND METHODS

Participants

The study adopts the experimental method through designing measurements before and after one training group. The sample consists of 16 players. The study applies 12-week exercise intervention to evaluate running economy and VO_{2max}. A pretesting is performed in the week prior to the intervention, and during the last week of the training session, a post-test is conducted. Pre-existing conditions are included in exclusion criteria including a history of injuries, injury of tendon or muscle, or any health conditions that violate the plyometric protocol. Before enrolment of the subjects, a number of information sessions are held to demonstrate the nature of the study, possible risks, and to answer any questions. A written consent is obtained from subjects before training or testing. The protocols and procedures of the study are approved by Institutional Review Board at the Faculty of Physical Education, Mansoura University. Table 1 shows the main characteristics of the study.

Table 1. Descriptive statistics of the subjects age, height, body fat, VO_{2max} and running economy.

Variable	Mean	SD	Median	Skewness
Age (yrs.)	21.00	.966	21.00	2.028-
Height (cm)	1.76	4.99	1.75	.346
Body fat (kg)	78.81	6.22	79.00	.302-
VO_{2max}	54.13	5.91	54.75	.307
Running Economy	43.87	4.63	45.40	240-

Training program

Sessions are performed every week, and each session consists of 25-30 minutes workout; exercises are required to be done with body weight only with no assistance or external resistance. Only one minute of recovery is allowed among all sets and exercises, and then more recovery time is permitted. The training intervention consists in a plyometric set that includes a series of 6 jumping exercises in every session; 1-2 sets of 8-16 reps in every jumping exercise. Exercises should be changed every other week. With respect to the exercises performed in the even weeks, they include double leg bound, bleacher hops, squat jumps, single leg hops, box or depth jumps, and alternate leg bound.

The research team provided the appropriate instructions and provided the needed assistance to all participants to ensure the safe application of all exercises. Participants have been greatly encouraged to complete all training sessions and are also permitted to stop for any reason at any point, especially in case of pain, discomfort, or injury. Subjects who have missed a training session or part of it were required to justify their absence. The details of plyometric protocols are given in Table 2.

Table 2. The plyometric training.

Week	Single leg hops	Bleacher hops	Double leg bound	Alternate leg bound	Squat jumps	Depth jumps	Box jumps
1	1 x 10		1 x 10		1 x 10		1 x 10
2		1 x 15		1 x 15		1 x 15	
3	2 x 10		2 x 10		2 x 10		2 x 10
4		2 x 10		2 x 10		2 x 10	
5	2 x 15		2 x 15		2 x 15		2 x 15
6		2 x 15		2 x 15		2 x 15	
7	3 x 10		3 x 10		3 x 10		3 x 10
8		3 x 10		3 x 10		3 x 10	
9	3 x 15		3 x 15		3 x 15		3 x 15
10		3 x 15		3 x 15		3 x 15	
11	4 x 10		4 x 10		4 x 10		4 x 10
12		4 x 10		4 x 10		4 x 10	

Determination of VO_{2max} 30-15 IFT

This technique includes 30-second shuttled runs with 15-second intervals or passive recovery periods. The speed is set to 8km./h for first 30 runs, then velocity is increased by 0.5 km/h every 30 runs. Two lines are set 40m apart (as shown in Figure 1) where participants should run back and forth between them. This exercise starts with a beep which helps players adjust their running speed in the middle of 3m zone and at each extremity. Players are required to walk forward during the 15-second intervals towards the nearest line (whether at the middle or end of the running area depending on the previous run and where it stops). Players have to complete the stages as much as they can; however, the test ends if players cannot maintain the decided running speed, or if they cannot complete the 3m zone with the beep three successive times. The velocity reached at the last stage reflects the player's VIFT that is used to calculate VO_{2max} through the following formula: VO_{2max} 30-15 IFT ($ml.1min.kg^{-1}$) = 28.3 - 2.15G - 0.741 A - 0.0357 W + 0.0586 A × VIFT + 1.03 VIFT, where A represents age, W represents weight, and G represents gender (female = 2, male = 1) (Buchheit et al., 2008).

Determination of running economy

Participants are asked to warm up for 7 minutes at 12km/h followed by 8 minutes at 14 km/h, then the VO_{2max} is measured between the 6th and 7th minute at 14 km/h because this represents the running economy of the athlete which is defined as the relation between running velocity and VO_{2max} (Guglielmo et al., 2009).

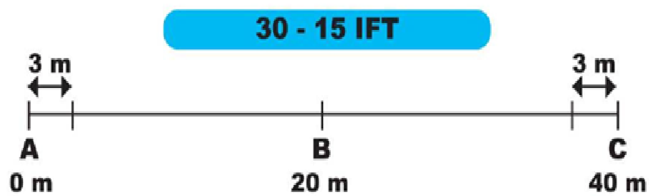

Figure 1. Diagram of the layout of the 30-15 IFT (intermittent fitness test).

Statistical analysis

Analysis of the data performed using the computer software SPSS 15.0 (SPSS, Chicago, IL, USA) Continuous data given as mean ± SD (standard deviation) and median (min–max). The data are analysed using Pearson correlation test. The significance level of $p < .05$ was adopted in all tests.

RESULTS

Table 3 illustrates the mean ± SD values of running economy before and after the intervention and the maximal rate of oxygen uptake. Pearson's Correlation test is used to analyse data, and a significance level of $p < .05$ was used in all tests.

Table 3. Subjects means, SD and test for VO_{2max} and running economy (n = 16).

Variable	**Subject**				**T**	***p***
	Pre		Post			
	mean	SD	mean	SD		
VO_{2max} ($mlkg^{-1}.min^{-1}$)	54.13	5.91	58.47	6.03	6.286-	2.602
Running Economy ($ml.kg^{-1}.min^{-1}$)	43.87	4.63	38.79	3.97	11.47	

Note. Significance level was set at (.01).

DISCUSSION

The present study concluded that plyometric training for 12 weeks enhanced the physiological markers of running economy and VO_{2max}. In a more detailed way, there are certain types of plyometric training that can stimulate specific neural adaptations like increased activation of motor units, less hypertrophy heavy-resistance strength training (Saunders et al., 2004; Saunders et al., 2006).

It has been found that plyometric training enables muscles to generate power by exaggerating stretch-shortening cycle. The study demonstrated an additional factor that increases the stiffness of muscle- tendon parts, which is the use of plyometric and speed training to enhance running economy for trained runners. Adding lower- limb strength and/ or plyometric training to endurance running for approximately 10 weeks induced an improvement in running economy 4-8% (Saunders et al., 2006). This may be due to neural adaptations that enable the player to perform a stretch- shortening cycle and improve running mechanisms (Paavolainen et al., 1999).

Thomas et al. demonstrated in 1995 that the improvement of running economy requires training to focus on improving physiological characteristics as HR, VE, LA regulation in order to minimize the energy associated with these parameters. Running economy can be improved by interval training through reducing VE, HR, LA at higher running speeds. A number of recent studies have reported an improvement in running economy after performing plyometric training for 6 weeks for moderately trained players. The former study indicated a 6% improvement in running economy and VO_{2max} through three running speeds, and a 3% increase in 3km running performance (King et al., 1985; Thomas et al., 1995).

Saunder et al., (2006) in their study of highly trained distance runners, they applied a 9-week program that included 3 sessions per week. The protocol applied included jumping and strength training with a high-velocity movement with a relatively low load. After 5 and 9 weeks of training, participants were tested, but no statistically significant change was detected in running economy in the 5-week training. Conversely, regarding the 9-week training, an improvement in plyometric group was observed at 18 km/h (the top 3 speeds). Participants were asked to perform the same exercise in week 9 but this time two new exercises were added: scissor jumps for height, and continuous hurdle jumps. The study has suggested two possible conclusions: either the added exercises are more effective or/ and demanding in running economy, or the statistically significant improvement required more than 5 weeks to be realized in a small group (Saunder et al., 2006).

Other studies have indicated a combination of explosive speed training and aerobics training can improve running economy and overall runners' performance at 3 km and 5 km (Paavolainen et al., (1999). The researchers attributed this to plyometric training and its modifications in running economy, considering that physiological indexes associated with aerobics efficiency (lactate and VO_{2max} response) show no significance change in these studies. Neural adaptation and increased ability to use stored elastic energy are considered among the possible mechanisms that may be responsible for improving running economy through plyometric training (Saunders et al., 2004; Wael et al., 2021).

Furthermore, most studies have asserted that running economy is enhanced due to training of untrained or moderately trained subjects, nonetheless, in the case of highly trained runners; this improvement can be achieved through different training methods, such as strength training, endurance training, and simultaneous explosive strength as players have already a well-developed running economy. Moreover, simulated moderate altitude can achieve adaptations through physiological systems that enhance performance and running economy (Saunders et al., 2004; Støren et al., 2008).

To date, the results have indicated a positive relation between improved running economy and VO_{2max} on the one hand, and plyometric training on the other, nevertheless, no reasons are stated to justify this relation. Consequently, it is necessary to conduct some comparative studies on speed and plyometric protocols in order to gain a better understanding of how to obtain the ultimate improvement of VO_{2max}, running economy, and performance of different players. A number of factors are used to determine the type of training most suitable for a player, and these factors include individual weaknesses and strengths, as well as the capacity to respond to training stimuli.

CONCLUSIONS

The present study demonstrated an improvement in running economy, VO_{2max} due to plyometric training. A clear understanding of the requirements of endurance running is considered a must in order to design a productive training program that can achieve the maximum potential of performance. It is also necessary to take into account risk factors and common injuries in order to avoid or alleviate them through the training program. It is also fundamental to consider the following important variables: length of program, volume of training (repetitions per set, sets per session, and sessions per week), number of exercises, specific exercises, and relative difficulty and stress of exercises. It should be noted that the optimal levels of these variables may vary due to the types of competitions, training, and population targeted.

AUTHORS CONTRIBUTIONS

Ramadan, W.A., contributed to conceptualization, formal analysis, methodology, supervision, validation, visualization, writing-review & editing. Elsayed, A. contributed to investigation, data extraction, data analysis and manuscript writing, results discussion. Ramadan, W.A., and Elsayed, A. contributed to supervision, writing-original draft, writing-review & editing. All authors read and approved the final manuscript.

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No potential conflict of interest were reported by the authors.

REFERENCES

Abdelkrim, N.; El Fazaa S.; El Ati, J. (2007). Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. British journal of sports medicine, 41(2): 69–75. https://doi.org/10.1136/bjsm.2006.032318

Billaut, F.; Basset, A.; Falgairette, G. (2005). Muscle coordination changes during intermittent cycling sprints. Neuroscience letters, 380(3): 265–269. https://doi.org/10.1016/j.neulet.2005.01.048

Buchheit, M. (2008). The 30-15 intermittent fitness test: accuracy for individualizing interval training of young intermittent sport players. Journal of strength and conditioning research, 22(2): 365–374. https://doi.org/10.1519/jsc.0b013e3181635b2e

Buchheit, M.; Spencer, M.; Ahmaidi, S. (2010). Reliability, usefulness, and validity of a repeated sprint and jump ability test. International journal of sports physiology and performance, 5(1): 3–17. https://doi.org/10.1123/ijspp.5.1.3

King, D.S.; Costill, D.L.; Fink, W.J.; Hargreaves, M.; Fielding, R. A. (1985). Muscle metabolism during exercise in the heat in unacclimatized and acclimatized humans. Journal of applied physiology (Bethesda, Md. : 1985), 59(5): 1350–1354. https://doi.org/10.1152/jappl.1985.59.5.1350

Prampero, P. (2003). Factors limiting maximal performance in humans. Eur J Appl Physiol, 90(1): 420–429. https://doi.org/10.1007/s00421-003-0926-z

Edge, J.; Bishop, D.; & Goodman, C. (2006). Effects of chronic NaHCO3 ingestion during interval training on changes to muscle buffer capacity, metabolism, and short-term endurance performance. Journal of applied physiology (Bethesda, Md.: 1985): 101(3), 918–925. https://doi.org/10.1152/japplphysiol.01534.2005

Guglielmo, L. G.; Greco, C. C.; & Denadai, B. S. (2009). Effects of strength training on running economy. International journal of sports medicine, 30(1): 27–32. https://doi.org/10.1055/s-2008-1038792

Joyner, M. J. (1991). Modeling: optimal marathon performance on the basis of physiological factors. Journal of applied physiology (Bethesda, Md. : 1985): 70(2), 683–687. https://doi.org/10.1152/jappl.1991.70.2.683

Mclaughlin, J. E.; Howely, E. T.; Bassett, D. R.; Thompson, D. L.; Fitzhugh, E. C. (2010). Test of the classic model for predicting endurance running performance. Medicine and science in sports and exercise, 42(5): 991–997. https://doi.org/10.1249/mss.0b013e3181c0669d

Paavolainen, L.; Hakkinen, K.; Hamalainen, I.; Nummela, A.; Rusko, H. (1999). Explosive-strength training improves 5-km running time by improving running economy and muscle power. Journal of applied physiology (Bethesda, Md. : 1985): 86(5), 1527–1533. https://doi.org/10.1152/jappl.1999.86.5.1527

Ross, A.; Leveritt, M.; Riek, S. (2001). Neural Influences on Sprint Running. Sports Med, 31(6): 409-25. https://doi.org/10.2165/00007256-200131060-00002

Saez de Villarreal, E.; Requena, B.; Cronin, J. (2012). The Effects of Plyometric Training on Sprint Performance: A Meta-Analysis. J. Strength Cond. Res, 26(2): 575-84. https://doi.org/10.1519/jsc.0b013e318220fd03

Saunders, P. U.; Pyne,D.B.; Telford, R.D.; Hawley, J. A. (2004). Factors affecting running economy in trained distance runners. Sports medicine (Auckland, N.Z.), 34(7): 465–485. https://doi.org/10.2165/00007256-200434070-00005

Saunders, P. U.; Pyne,D.B.; Telford, R.D.; Hawley, J. A. (2004). Reliability and variability of running economy in elite distance runners. Medicine and science in sports and exercise, 36(11): 1972–1976. https://doi.org/10.1249/01.mss.0000145468.17329.9f

Saunders, P. U.; Telford, R. D.; Pyne, D. B.; Peltola, E. M.; Cunningham, R. B.; Gore, C. J.; Hawly, J. A. (2006). Short-term plyometric training improves running economy in highly trained middle and long distance runners. Journal of strength and conditioning research, 20(4): 947–954. https://doi.org/10.1519/00124278-200611000-00036

Sheppard, J. M.; Gabbett, T.; Taylor, K. L.; Dorman, J.; Lebedew, A.J.; Borgeaud, R. (2007). Development of a repeated-effort test for elite men's volleyball. International journal of sports physiology and performance, 2(3): 292–304. https://doi.org/10.1123/ijspp.2.3.292

Stone, N. M.; Kilding, A. E. (2009). Aerobic conditioning for team sport athletes. Sports medicine (Auckland, N.Z.), 39(8): 615–642. https://doi.org/10.2165/00007256-200939080-00002

Storen, O.; Helgerud, J.; Stoa, E. M.; Hoff, J. (2008). Maximal strength training improves running economy in distance runners. Medicine and science in sports and exercise, 40(6): 1087–1092. https://doi.org/10.1249/mss.0b013e318168da2f

Thomas D. Q.; Fernhall, B.; Blanpied, P. (1995). Changes in running economy and mechanics during a 5 km run. J Strength Cond Res, 9(1): 5-170. https://doi.org/10.1519/1533-4287(1995)009<0170:cieam>2.3.co;2

Wael, R.; Chrysovalantou, X.; Refaat, M.; Amr, S.; Sandra, A. B. (2021). Effect of wearing an alevation training mask on physiological adaptation. Journal of Physical Education & Sport, 21(3), 170, 1337-1345.