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Metabolic Profile of Football Athletes During Running Incorporating Different Levels of Direction Change

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Abstract

We evaluated the metabolic profile of football athletes during running incorporating different levels of direction change. A total of 34 male football athletes performed a running test in the laboratory and two running tests in a gymnasium. The laboratory running test (0-TURN) included continuous forward running and was performed on a motorized treadmill. The two running tests conducted in the gymnasium involved repetitive bouts of continuous running for 20 m followed by directional changes of either 90° (90-TURN test) or 180°(180-TURN test). Repeated-measures analysis of variance comparing results in the three running tests revealed statistically significant main effects in maximal oxygen uptake (VO_{2max}), blood lactate concentration, and maximum heart rate ($p<0.05$) but not in maximal accumulated oxygen deficit ($p>0.05$). Post hoc t tests incorporating a Bonferroni correction revealed that the VO_{2max} was similar in the 0-TURN and the 90-TURN tests ($p>0.05$). However, statistically significant differences in VO_{2max} were observed between the 0-TURN and the 180-TURN tests as well as between the 90-TURN and the 180-TURN tests ($p<0.001$). The lowest values of blood lactate concentration were measured after the 90-TURN test, while the highest were recorded following the 180-TURN test ($p<0.001$). Finally, the maximum heart rate was similar in the 0-TURN and the 90-TURN tests ($p>0.05$), but it was significantly augmented in the 180-TURN tests ($p<0.05$).Based on the present results, we conclude that increasing the angle of direction change from 0°, to 90°, and, finally, to 180° during intermittent running in football athletes results in significantly increased metabolic demands.

Key words: *maximal oxygen uptake, blood lactate, oxygen deficit, multidirectional running*

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Ερευνητική

Μεταβολικό Προφίλ Αθλητών Ποδοσφαίρου κατά το Τρέξιμο με Διαφορετικές Γωνίες Αλλαγής Κατεύθυνσης

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Περίληψη

Σκοπός της μελέτης ήταν να αξιολογηθεί το μεταβολικό προφίλ αθλητών ποδοσφαίρου κατά το τρέξιμο με διαφορετικές γωνίες αλλαγής κατεύθυνσης. Συνολικά 34 αθλητές ποδοσφαίρου εκτέλεσαν μια δοκιμασία τρεξίματος στο εργαστήριο και δύο δοκιμασίες σε γυμναστήριο. Η εργαστηριακή δοκιμασία (0-ΣΤΡΟΦΗ) περιελάμβανε συνεχόμενο τρέξιμο προς τα εμπρός σε διάδρομο τρεξίματος. Οι δύο δοκιμασίες που πραγματοποιήθηκαν στο γυμναστήριο περιελάμβαναν επαναλαμβανόμενο τρέξιμο για 20 μέτρα, ακολουθούμενο από αλλαγές κατεύθυνσης είτε 90° (90-ΣΤΡΟΦΗ) είτε 180° (180-ΣΤΡΟΦΗ). Επαναλαμβανόμενες μετρήσεις ανάλυσης διακύμανσης στις τρεις δοκιμασίες έδειξαν στατιστικά σημαντικές κύριες επιδράσεις στη μέγιστη πρόσληψη οξυγόνου (VO_{2max}), τη συγκέντρωση γαλακτικού οξέος στο αίμα και τη μέγιστη καρδιακή συχνότητα ($p<0.05$), αλλά όχι στο έλλειμμα οξυγόνου ($p> 0.05$). Post hoc t τέστ με ενσωματωμένη διόρθωση Bonferroni έδειξαν ότι οι τιμές της VO_{2max} ήταν όμοιες στις δοκιμασίες 0-ΣΤΡΟΦΗ και 90-ΣΤΡΟΦΗ ($p>0.05$), αλλά σημαντικά αυξημένες κατά τη δοκιμασία 180-ΣΤΡΟΦΗ ($p<0.001$). Οι χαμηλότερες τιμές της συγκέντρωσης γαλακτικού οξέος στο αίμα μετρήθηκαν μετά τη δοκιμή 90-ΣΤΡΟΦΗ, ενώ οι υψηλότερες καταγράφτηκαν μετά τη δοκιμασία 180-ΣΤΡΟΦΗ ($p<0.001$). Τέλος, οι τιμές της μέγιστης καρδιακής συχνότητας ήταν όμοιες στις δοκιμασίες 0-ΣΤΡΟΦΗ και 90-ΣΤΡΟΦΗ ($p>0.05$) αλλά σημαντικά αυξημένες κατά τη δοκιμασία 180-ΣΤΡΟΦΗ ($p<0.05$). Συμπεραίνεται ότι η αύξηση της γωνίας αλλαγής κατεύθυνσης από 0°, στις 90° και, τέλος, στις 180° κατά το τρέξιμο σε αθλητές ποδοσφαίρου συνοδεύεται με σημαντικά αυξημένες μεταβολικές απαιτήσεις.

Λέξεις κλειδιά: *μέγιστη πρόσληψη οξυγόνου, γαλακτικό οξύ, έλλειμμα οξυγόνου, τρέξιμο*

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Introduction

Football performance is dependent on a combination of physical, technical and tactical characteristics of match play. The physical and tactical characteristics are crucial for performance in contemporary football because the physical demands of match play are increasing (Bradley et al., 2013; Lago-Ballesteros, Lago-Penas, & Rey, 2012). Current research shows that total distance covered has increased by ~2%, while distances of high-intensity running and sprinting have increased by 30–50%compared to a few years ago (Barnes, Archer, Hogg, Bush, & Bradley, 2014; Wallace & Norton, 2014). At present, 7-12% and 1-4% of the overall distance covered by athletes is comprised of high-intensity running and sprinting, respectively (Bradley et al., 2009; Di Salvo et al., 2010). It appears, therefore, that the physical requirements of contemporary football match-play, primarily for high-intensity running, have significantly increased. This is in line with published data showing that football performance is associated more with intermittent exercise capacity than with maximal oxygen uptake (VO_{2max}) (Iaia, Rampinini, & Bangsbo, 2009; Krustrup & Bangsbo, 2001).

The nature of football match play is characterized by an integration of multidirectional physical actions and technical skills (Bradley et al., 2009; Wallace & Norton, 2014). The aforementioned changes in the physical demands of contemporary football may be driven by changes in tactics and playing systems. For instance, when in possession, current match play strategies and tactical formations dictate that running without the ball is of paramount importance whether it is for fast breaks, running into space, accelerating to get to loose balls first, or running on to through-passes. When possession is lost, athletes must quickly recover from attacking positions into defensive areas, increasing the number of defensive players behind the ball and therefore reducing the space for attacking play (Bangsbo & Peitersen, 2002; Wallace & Norton, 2014). Given the paramount importance of multidirectional intermittent exercise and running without the ball in football, it is necessary to investigate the metabolic requirements of such physical actions. Nevertheless, to our knowledge, no such data exist in the literature. Therefore, the purpose of the present study was to evaluate the metabolic profile of football athletes during running incorporating different levels of direction change.

Methodology

Subjects

The study was conducted according to the principles expressed in the Declaration of Helsinki and was approved by the University of Thessaly Ethics Review Board. A total of 34 healthy [no history of respiratory, metabolic, or cardiovascular conditions; age: 21.2 ± 2.8 years; height: 175.1 ± 4.3 cm; weight: 70.7 ± 5.1 kg; body mass index: 23.0 ± 1.3; training experience: 6.1 ± 0.9; (mean±SD)] non-smoking male football athletes were informed of all experimental procedures, associated risks, and discomforts, and provided written consent to participate in the study.

Experimental protocol

Within a 30-day period, participants underwent a running test in the laboratory and two running tests in an indoor gymnasium. Prior to each visit, participants were familiarized with all assessment protocols and were asked to fast for a minimum of 8 hours as well as to refrain from intense exercise (running, swimming, cycling, weight lifting, etc.), other excessive stressors, alcohol, and the use of over-the-counter medications for 24 hours before, and caffeine for 12 hours before the experimental session. Tests were conducted individually to eliminate competition bias, at least four days apart, and in a random order, by the same investigators and between 08:00h and 12:00h. Measurements of the targeted variables were conducted using identical pre-calibrated equipment. The ambient conditions in the laboratory were set to match those of normal indoor conditions for temperature (28-30°C) and relative humidity (35-45%) during all measurements.

After receiving an orientation to the instrumentation and experimental protocols and providing informed consent, we recorded training experience and biological age (accurate to 1 month) of all participants. Standing height was measured (accurate to the nearest 0.5 cm) using a Seca Stadiometer 208 (Seca Corporation, Hamburg, Germany) while participants' shoes were removed and their head was at the Frankfort horizontal plane. Body mass (accurate to the nearest 0.5 kg) was assessed with a Seca Beam Balance 710 (Seca Corporation, Hamburg, Germany).

The laboratory running test (0-TURN) included continuous forward running and was performed on a motorized treadmill (Powerjog, GXC200, UK) whereas the two other running tests were performed in an indoor rubber-floored gymnasium. Speed throughout all protocols was regulated in an identical manner. Specifically, athletes started exercising at 8.5 km $\cdot h^{-1}$ and speed was increased by 0.5 km $\cdot h^{-1}$ every minute until volitional exhaustion. The two running tests conducted in the gymnasium involved intermittent running incorporating different levels of direction change. Specifically, one test (90-TURN) involved repetitive bouts of continuous running for 20 m at the predetermined speed followed by directional change of 90°. The other test (180-TURN) involved repetitive bouts of continuous running for 20 m at the predetermined speed followed by directional change of 180°.

During all running tests, participants exercised while breathing through a facemask and having their pulmonary ventilation continually monitored by a K4b^2 (Cosmed, Rome, Italy) portable gas analyzer. The VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) was measured via open circuit spirometry. Moreover, maximal accumulated oxygen deficit (MAOD) was calculated as the difference between the predicted oxygen demand and the accumulated oxygen uptake using standardized procedures (Medbo et al., 1988). Heart rate was monitored through short range telemetry with a Polar S810 (Kempele, Finland).

At completion of each running test, participants remained seated and 10 µl of capillary blood were taken from the fingertip of the 4^{th} finger (ring finger) at the 5^{th} minute of recovery to determine blood lactate concentration. The sample was collected in a disposable calibrated non heparinized capillary tube and was immediately put into reagent solution for subsequent analysis by photometric method (Mini-photometer plus LP 20, Dr Lange GmbH, Berlin, Germany).

Statistical analysis

Repeated-measures analysis of variance followed by post hoc t tests incorporating a Bonferroni correction was used to compare results for all variables in the three running tests. Associations in the three running tests were examined using Pearson's product-moment correlation coefficient. The level of significance was set at $p<0.05$. All values are reported as mean ± standard deviation.

Results

The results of the repeated-measures analysis of all variables are depicted in Table 1. Repeated-measures analysis of variance comparing values of all variables in the three running tests demonstrated statistically significant main effects in VO_{2max}, blood lactate concentration, and maximum heart rate ($p<0.05$) but not in MAOD ($p>0.05$). Post hoc t tests incorporating a Bonferroni correction revealed that the VO_{2max} was similar in the 0-TURN and the 90-TURN tests ($p>0.05$). However, statistically significant differences in VO_{2max} were observed between the 0-TURN and the 180-TURN tests as well as between the 90-TURN and the 180-TURN tests ($p<0.001$). The lowest values of blood lactate concentration were measured after the 90-TURN test, while the highest were recorded following the 180-TURN test ($p<0.001$). No pairwise differences were detected in terms of MAOD ($p>0.05$). Finally, the maximum heart rate was similar in the 0-TURN and the 90-TURN tests ($p>0.05$). However, statistically significant differences in the maximum heart rate were observed between the 0-TURN and the 180-TURN tests as well as between the 90-TURN and the 180-TURN tests ($p=0.003$).

Table 1. Study results and comparisons in the three running tests

	0-TURN	90-TURN	180-TURN
VO_{2max} (ml ·kg^{-1} ·min^{-1})	55.4 ± 6.7†	55.2 ± 7.5‡	59.5 ± 6.2†‡
Blood lactate (mmol ·L^{-1})	10.0 ± 1.2*†	9.4 ± 2.1*‡	11.1 ± 2.6†‡
MAOD (ml)	1176.0 ± 270.5	1210.0 ± 222.2	1253.4 ± 373.4
Maximum heart rate (beats ·min^{-1})	193.9 ± 6.8†	194.3 ± 9.8‡	198.6 ± 6.7†‡

Key:* = statistically significant (p<0.05) difference between 0-TURN and 90-TURN;
† = statistically significant (p<0.05) difference between 0-TURN and 180-TURN;
‡ = statistically significant (p<0.05) difference between 90-TURN and 180-TURN.

Note: 0-TURN = running test incorporating continuous forward running; 90-TURN = running test incorporating intermittent running with 90°direction changes; 180-TURN = running test incorporating intermittent running with 180° direction changes; VO_{2max} = maximum oxygen uptake; MAOD = maximal accumulated oxygen deficit.

Table 2 presents pairwise associations between the three running tests. Our results demonstrated that values of VO_{2max}, blood lactate concentration, and MAOD were highly associated between all tests (p<0.001). On the other hand, maximum heart rate values between the 0-TURN and the 90-TURN tests were not associated (p>0.05). Statistically significant correlations of moderate strength were detected in the maximum heart rate values between the 0-TURN and the 180-TURN tests, as well between the 90-TURN and the 180-TURN tests.

Table 2. Associations (r with accompanying p values in subscript) between the three running tests

	0-TURN and 90-TURN	0-TURN and 180-TURN	90-TURN and 180-TURN
VO_{2max}	$0.854_{<0.001}$	$0.755_{<0.001}$	$0.814_{<0.001}$
Blood lactate	$0.825_{<0.001}$	$0.648_{<0.001}$	$0.823_{<0.001}$
MAOD	$0.900_{<0.001}$	$0.640_{<0.001}$	$0.609_{<0.001}$
Maximum heart rate	$0.285_{0.102}$	$0.452_{0.007}$	$0.613_{<0.001}$

Note: VO_{2max} = maximum oxygen uptake; MAOD = maximal accumulated oxygen deficit.

Discussion

The purpose of the present study was to evaluate the metabolic profile of football athletes during running incorporating different levels of direction change. This is important given the paramount importance of multidirectional intermittent running without the ball in contemporary football. Our results indicate that increasing the angle of direction change has a potent effect on metabolic demands. Indeed, all metabolic variables that we assessed were increased as the angle of direction change increased from 0°, to 90°, and, finally, to 180°. This resulted in statistically significant effects in all variables except MAOD. The latter was probably due to a significant amount of variation observed in this variable.

Contemporary football positional tactics and playing systems dictate an increasing amount of intermittent multidirectional running without the ball. When in possession, intermittent multidirectional running without the ball is of paramount importance for fast breaks, running into space, accelerating to get to loose balls first, or running on to through-passes. When possession is lost, athletes must quickly recover from attacking positions into defensive areas, increasing the number of defensive players behind the ball and therefore reducing the space for attacking play (Bangsbo & Peitersen, 2002; Wallace & Norton, 2014). These notions are strengthened by the fact that most football teams now focus on possession-based strategies, awaiting opportunities to exploit gaps in the opposition's defence by moving players around the field. Playing systems are designed to use running without the ball and short to medium distance passes aiming to find weakness in the opposition defence (Bangsbo & Peitersen, 2004; Tipping, 2007). This is supported by recent evidence demonstrating that plays in English Premier League in the 2012-2013 football season are characterized by an increase in the number of passes per shot compared to the season 2006-7 (Bush, Barnes, Archer, Hogg, & Bradley, 2015).

Based on the present results, we conclude that increasing the angle of direction change from 0°, to 90°, and, finally, to 180°during intermittent running in football athletes results in significantly increased metabolic demands. Future studies should examine training programmes that increase performance of intermittent multidirectional running without the ball in football.

Implications for competitive sports

Our results suggest that coaches should be aware of the increased metabolic demands of intermittent multidirectional running without the ball and should consider this in their positional tactics and playing systems. Moreover, our results are applicable to player recruitment, as they can be used to improve player identification based on the system and style of play of the recruiting club. In addition, the current results relate to the physical preparation of athletes during pre-season as well as during the entire year. Indeed, our results suggest that coaches who adopt the aforementioned positional tactics and playing systems must ensure that their athletes have a high level of aerobic and anaerobic capacity. The latter should be further developed in players who will be required to perform intermittent multidirectional running without the ball during the match. In turn, this could be achieved through individual drills for each player and/or position or ideally during drills that simulate intense periods of match-play (e.g. full backs sprint whilst creating overlaps with wide midfielders followed by recovery runs).

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