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Research article

Postural control after a prolonged treadmill run at individual ventilatory and anaerobic threshold

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Abstract
The objective of the study was to verify whether young males' balance was affected by 30min prolonged treadmill running (TR) at individual ventilatory (IVT) and anaerobic (IAT) thresholds in recovery time. The VO_{2max}, IAT and IVT during an incremental TR were determined. Mean displacement amplitude (*A*cp) and velocity (*V*cp) of center of pressure were recorded before (pre) and after (0min post; 5min post; and 10min post) prolonged TR at IAT and IVT, through posturographic trials performed with eyes open (EO) and closed (EC). Significant differences between IVT and IAT for *V*cp, between EO and EC for *A*cp and *V*cp, were observed. The IAT induced higher destabilizing effect when postural trials were performed with EC. The IVT intensity produced also a destabilizing effect on postural control immediately after exercise. An impairment of postural control after prolonged treadmill running exercise at IVT and IAT intensity was showed. However, destabilizing effect on postural control disappeared within 10min after IAT intensity and within 5min after IVT intensity.

Key words: Posture, vision, ventilatory threshold, anaerobic threshold.

Introduction

Postural control is dependent upon visual, vestibular and proprioceptive feedback, and reflexive and voluntary muscle responses (Nagy et al., 2004). Balance is actively controlled by the central nervous system, which calls into action the various relevant postural muscles, as and when needed (Gribble and Hertel, 2004; Nardone et al., 1997).

A deterioration of postural control due to muscular fatigue was reported by Vuillerme et al. (2007). Fatigue following a physical exercise is caused by a combination of physiological processes, occurring at both central and peripheral levels, which mainly deal with the inability to produce an expected force or with the increase in the onset delay of postural control movements (Bove et al., 2007; Gribble and Hertel, 2004; Springer and Pincivero, 2009). Vision allows individuals to compensate the destabilizing effect induced by calf muscular fatigue on postural sway during standing (Vuillerme et al., 2001).

The effect of prolonged exercise on postural control has been investigated in both trained (Lepers et al., 1997) and untrained subjects (Nardone et al., 1997; 1998). All studies showed a decrease in balance ability after fatiguing exercise. Moreover, the type of activity could also produce a different effect on postural control after exercise (Mello et al., 2010). The studies on postural changes after exercise showed an exercise intensity or workload defined as a percentage of maximum heart rate (Nardone et al., 1997; 1998) or as a percentage of maximal oxygen uptake (VO_2 max) (Lepers et al., 1997). Meyer (1999) suggested that exercise intensity should be defined in relation to the individual anerobic threshold (IAT) and individual ventilatory threshold (IVT), because when a workload is quantified only in relation to VO_{2max} or HR_{max}, it can result in different intensity between subjects.

Some studies have investigated the effect on postural control of specific physical activities such as gymnastics (Asseman et al., 2008), classical dance (Guidetti and Pulejo, 1996; Golomer et al., 1997), acrobatics (Golomer et al., 1997), biathlon shooting (Groslambert et al., 1999), basketball (Kioumourtzoglou et al., 1998), and triathlon (Nagy et al., 2004). Several authors have studied the return to baseline of postural control measures in the recovery time immediately after fatiguing exercise (Dickin and Doan, 2008; Fox et al., 2008). Considering Fox's findings that effect of exertion lasted up to 13 minutes after each exercise was completed, we would confirm his findings, making two experimental observations after exercise (5 and 10 minute), and the effect of exertion immediately after each exercise (0 minute).

Therefore, the aim of this study was to verify whether young male soccer players' balance was significantly affected by 30min prolonged treadmill running at IAT and IVT intensity in recovery time immediately after exercise (0min post), after 5min (5min post), and after 10min (10min post) within each exercise intensity level.

Methods

Participants

The sample was composed by 18 young male individuals regularly involved in curricular training at the University of Rome "Foro Italico". Mean age was 21.8 ± 1.4 yr. The height, weight and BMI were 1.79 ± 0.04 m, 72.4 ± 8.0 kg, and 22.7 ± 1.7 $kg \cdot m^{-2}$ respectively.

All the subjects had been training regularly for approximately 5 days per week (3–4 h per day) for the previous 5 years at least, and were competing in semi-professional competitions, organized by the Italian Soccer Federation (FIGC), at the time of the study. The soccer players' experience was 14 ± 2 yr (range 11-16 yr). Therefore, they performed soccer training for 15-20 hours per week, and a curricular training (physical activity lessons in the University) for 7 hours per week.

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All subjects signed written informed consent forms that were reviewed by the Institutional Review Board for Human subjects of the University of Rome "Foro Italico" to ensure that all subjects were knowledgeable of the normal risks and procedures involved in the study.

Experimental protocol

During the pre-session test, each subject was assessed to determine anthropometric measurements and subsequently to depict VO_{2max}, IAT and IVT during an incremental treadmill running test until exhaustion. In the following two experimental sessions, the subjects performed a 30min prolonged treadmill running test at IVT and IAT intensity.

Pre-session test

To determine the VO_{2max}, IVT and IAT, each subject performed an incremental running test until exhaustion using a Woodway Pro Series treadmill (Waukesha, USA). VO_2, ventilation (VE) and heart rate (HR) were recorded as average values every 30s during the test by a telemetric oxygen uptake open-circuit system (K4 b^2 COSMED, Rome, Italy).

The treadmill test consisted of a 3-min walking warm-up at 6 $km{\cdot}h^{-1}$ with a 0% of slope, with an initial running speed of 9 $km{\cdot}h^{-1}$, followed by speed increment of 2 km/h every 3 min up to the workload subsequent to IAT (the second increment in blood lactate (La) $\geq$0.5 $mmol{\cdot}l^{-1}$). Then, every 1 min an increment in slope of 3% was given. All subjects were urged to complete the highest work level possible. When the VO_{2max} was obtained, an active recovery of 1-min walking at 5 km/h with a 0% slope followed (Baldari, 2000). During pre-session exercise test, VO_{2max}, IVT, IAT were determined, as previously described (Baldari et al., 2004).

Determination of blood lactate was carried out using capillary blood from a fingertip. Blood lactate concentration was immediately analyzed during the treadmill test using an AccuTrend lactate analyzer. Blood lactate evaluations were performed at the 3rd minute of a given work load, for each work level until the workload subsequent to that corresponding to the IAT. Blood lactate determinations were performed also at the 3rd, 6th and 10th min of the recovery phase (Baldari, 2009).

Experimental sessions

During the experimental session, the subject performed a prolonged treadmill running test for a period of 30min at the IVT or IAT intensity, after a 3min walking warm-up at 6 $km{\cdot}h^{-1}$.

Before, during and after each experimental session HR, VE, VO_2 and VCO_2 were continuously monitored breath by breath through a telemetric oxygen uptake measurements system. Then off line, for each exercise, the VO_2 average of the last 30s was determined. La measurements were performed before exercise and every 5 minutes without running interruption. Before (pre) and after experimental sessions (at 0min post, 5min post and 10min post), the participants were assessed through the posturographic test. They stood barefoot on a force strain-gauge platform and assumed the orthostatic position that consisted in maintaining the standing position with the feet close together. During the test, the subjects were reminded to stand naturally and comfortably with their arms hanging free at their sides and to fix their visual focus at eye level on a ruler placed on the opposite wall at the distance of 5m. Each posturographic test included both eyes open (EO) and eyes closed (EC) trials in a random order and subjects were required to sway as little as possible for 30s (Figura, 1991). The outputs of this circuitry were the vertical component of the ground reaction force and the reaction moments about the lateral and antero-posterior axes. These signals were sampled at frequency of 25 Hz by an A/D converter and fed into a personal computer to obtain a resultant centre of foot pressure (CP). Mean displacement amplitude (*A*cp) and velocity (*V*cp) were observed to describe the participants' postural behaviour. *A*cp indicates the maximal excursion of CP in any direction. It is a global measure that allows to estimate overall postural performance (i.e., stability) (Rival et al., 2005). *V*cp indicates the mean speed of CP displacements over the sampled period. It is the sum of the displacement scalars (i.e., the cumulated distance over the sampling period divided by the sampling time). This measure has been suggested to represent the amount of activity required to maintain stability, providing a more functional approach of posture (Rival et al., 2005). Therefore, high values of *A*cp indicate a great postural instability, while high values of *V*cp indicate a great balacing activity (Asseman et al., 2005; Figura et al., 1991).

Statistical analysis

The mean and standard deviation of all dependent variables were computed. Postural control variables (*A*cp, and *V*cp) were analyzed using a multivariate analysis of variance (MANOVA) with exercise intensity as the first factor (IVT and IAT), time as the second factor (pre, 0min post, 5min post, 10min post), and vision as the third factor (EO and EC) with repeated measures on all factors.

For each main factor and interaction effect, a post hoc analysis was conducted using the Scheffé's method. The level of significance was set at a $p < 0.05$.

Results

The HR before exercise was 73 ± 10 $beats{\cdot}min^{-1}$. The values of VO_2, % VO_{2max}, HR, La and treadmill running velocity during IVT exercise were 31 ± 2 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$, 51 ± 5 % VO_{2max}, 149±13.4 $beats{\cdot}min^{-1}$, 1.6±0.4 $mmol{\cdot}l^{-1}$, and 8.3±0.6 km/h respectively. The values of VO_2, % VO_{2max}, HR and treadmill running velocity during IAT exercise were 43 ± 4 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$, 70 ± 4 % VO_{2max}, 184 ± 7.5 $beats{\cdot}min^{-1}$, 3.9±0.4 $mmol{\cdot}l^{-1}$, and 11.3 ± 0.5 $km{\cdot}h^{-1}$ respectively.

The MANOVA with repeated measures showed a significant interaction between exercise intensity and vision ($F = 3.04$, $p < 0.05$), main effect of exercise intensity ($F = 12.38$, $p < 0.01$), vision ($F = 95.17$, $p < 0.01$), and time ($F = 13.72$, $p < 0.01$) for *A*cp and *V*cp.

The Figure 1 and 2 shows the significant differences between exercise intensity, vision, and time effect for for *A*cp and *V*cp, respectively. *A*cp was significantly higher at EC vs EO ($p < 0.01$); at 0min post vs pre, 5min post and 10min post ($p < 0.01$); and 5min post vs pre ($p < 0.05$). *V*cp was significantly higher at 0min post vs pre, 5min post and 10min post ($p < 0.01$); and 5min post vs 10min post ($p < 0.05$).

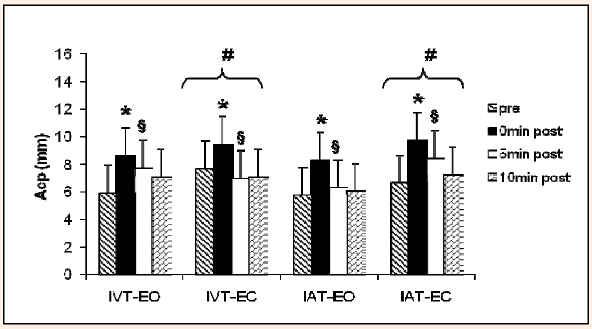

Figure 1. Mean values and standard deviations of interaction effect between exercise intensity (IAT and IVT), vision (EO and EC), and time (pre, 0min post, 5min post, and 10min post) for Acp. Significant differences ($p<0.01$): * 0min post vs pre, 5min post, and 10min post; § 5min post vs pre; and # EC vs EO.

At IVT exercise, *A*cp with EO showed significantly higher values at 0min post vs pre and 10min post ($p < 0.01$, $p < 0.05$ respectively), and at 5min post vs pre ($p < 0.01$). *A*cp with EC showed significant higher values at 0min post vs pre, 5min post and 10min post ($p < 0.05$, $p < 0.01$, $p < 0.01$ respectively) (Figure 1). *V*cp with EO showed higher values at 0min post vs pre, 5min post and 10min post ($p < 0.01$, $p < 0.05$, $p < 0.01$ respectively). *V*cp with EC showed significantly higher values at 0min post vs 5min post and 10min post ($p < 0.01$) (Figure 2).

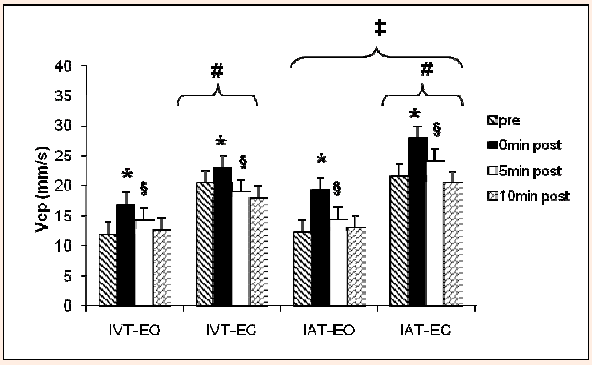

Figure 2. Mean values and standard deviations of interaction effect between exercise intensity (IAT and IVT), vision (EO and EC), and time (pre, 0min post, 5min post, and 10min post) for Vcp. Significant differences ($p<0.01$): * 0min post vs pre, 5min post, and 10min post; § 5min post vs pre; # EC vs EO; and ‡ IAT vs IVT.

At IAT exercise, *A*cp with EO showed significantly higher values at 0min post vs pre, 5min post and 10 min post ($p < 0.01$). *A*cp with EC showed significantly higher values at 0min post vs pre and 10min post ($p<0.01$), and at 5min post vs pre ($p<0.05$) (Figure 1). *V*cp with EO showed significantly higher values at 0min post vs pre, 5min post and 10min post ($p<0.01$). *V*cp with EC showed significantly higher values at 0min post vs pre and 10min post ($p<0.01$) (Figure 2).

Discussion

The findings of this study showed that 30min treadmill running at IVT and IAT intensities produced different changes on postural control in trained subjects. The body sway effects appeared immediately after the exercise and vanished within about 10min, confirming other studies (Bove et al., 2007; Fox et al., 2008). The body sway effects were induced by the exercise intensity (IVT or IAT) and visual conditions (EO or EC).

Body sway increased in all experimental conditions immediately after exercise. In fact, both *A*cp and *V*cp values were significantly increased after IVT and IAT exercise both with EO and EC condition, except for *V*cp after IVT with EC (p=0.09). Therefore, after both prolonged exercises there was a lower level of postural sway involving greater amplitude of CP displacements with increased balancing activity. This result confirmed previous studies showing an impairment of postural control after strenuous exercise (Bove et al., 2007; Lepers et al., 1997; Springer and Pincivero, 2009). Nardone (1998) studied the time course of body sway through three postural trials at 8, 28 and 68min after treadmill walking exercise. Fatigue-induced increases on body sway were observed in first postural trial followed by a plateau, full recovery was already recorded in the second postural trial (Nardone et al., 1998). Therefore, our investigation also analyzed the time course of body sway within 10min after treadmill run. Immediately after both IVT and IAT exercises, all postural variables showed a destabilizing effect. The postural instability (*A*cp), observed immediately after exercise, disappeared within 10min, whereas the balancing activity (*V*cp) returned to basal values within 5min.

The major findings of this study suggest that combining the exercise intensity and vision can significantly impact on body sway. In particular the destabilizing effect of exercise at two intensities on body sway was similar when postural trials were performed with EO. Instead, a grater destabilizing effect on postural control was shown with EC after IAT exercise.

The finding of this investigation that IVT exercise induced an *A*cp increase is in disagreement with Nardone's results (1997), in which lower exercise intensity produced no significant destabilizing effects. This different finding could be explained because Nardone (1997) assessed the body sway through the first postural trial at 5min after exercise; instead we assessed the body sway immediately after exercise without recovery. Moreover, Nardone (1997) studied the body sway after treadmill walking exercise; instead we analyzed the postural control after a treadmill run. In fact, it has been reported that different type of activity could produce a different effect on postural control after exercise (Lepers et al., 1997; Nagy et al., 2004; Nardone, 1997).

The postural control was influenced by visual, vestibular and somatosensation inputs (Nagy et al., 2004). It has been demonstrated that the visual input in postural control was affected by exercise (Derave et al., 2002) and subjects made less effective use of vestibular input (Lepers, 1997). Moreover, somatosensory input may be altered due to fatigue so it could result in deficits in neuromuscular control as represented through deficits in postural control (Gribble and Hertel, 2004; Nashner and Berthoz, 1978). These results suggested that running could disturb the postural stability, due probably to the more excessive head movement and disturbance of the vestibular and visual information centers. It has been claimed that levels of postural sway following running was also related to the conflict of information between the somatosensory and visual inputs during treadmill running (Hashiba, 1998). After modification of the sensory inputs available, individuals needed to redefine the respective contributions of the different sources of sensory information in order to regulate posture (Nagy et al., 2004). This decrease could explain the impairment of postural control especially with EC at 0min post. Moreover, the greater destabilizing effect on postural control with EC after IAT exercise could be a consequence of higher stimulation of otholitic system by linear head acceleration, higher conflict of information between somatosensory and visual inputs, and muscular fatigue during a running at higher speed.

Immediately after treadmill run, all subjects in this study had a self-motion perception, confirming the observations by Nardone (1997) and Derave (2002). Several authors, in fact, allowed a period from 30 seconds (Derave et al., 2002) to 3 minutes (Nardone et al., 1997) of resting before performing the posturographic tests. From this study, it is interesting to notice that immediately after IVT exercise the *A*cp increased and returned to baseline more quickly with EC than EO (5min post and 10min post respectively), and *V*cp returned to baseline even more quickly (0min post and 5min post respectively). This could indicate that after IVT exercise, the EC condition could reduce the effect of visual-somatosensory/motor conflict, decreasing the self-motion perceived immediately after treadmill running (Derave, 2002).

Conclusion

Several studies showed the risk of accident due to impairment of balance ability is grater in fatigued individuals. The accidents occur most frequently at the end of a sporting event or a training session, when a person is fatigued. Although the athletes usually train on the field, many athletes (competitive and recreational level) use often during their training session the gym equipment, and this kind of training includes prolonged running on a treadmill. Therefore, the findings of this investigation showed an impairment of postural control after prolonged treadmill running exercise at IVT and IAT intensity. The IAT intensity especially induced higher destabilizing effect when postural trials were performed with EC. The IVT intensity produced also a destabilizing effect on postural control immediately after exercise. However, destabilizing effect on postural control disappeared within 10min after IAT intensity and within 5min after IVT intensity.

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Key points

- To verify whether young males' balance was affected by 30min prolonged treadmill running at individual ventilatory and anaerobic thresholds in recovery time.
- Mean displacement amplitude and velocity of foot pressure center were recorded before and after prolonged treadmill running at individual ventilatory and anaerobic thresholds, through posturographic trials performed with eyes open and closed.
- Destabilizing effect on postural control disappeared within 10min post individual anaerobic threshold, and within 5min post individual ventilatory threshold.

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