Thieme

Wearing Colored Glasses can Influence Exercise Performance and Testosterone concentration?

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ABSTRACT

Perception of red color is associated with higher testosterone concentration and better human performance. Thus, we evaluated the acute effects of wearing colored-lens glasses on the YoYo intermittent endurance exercise test 2 (YoYoIE2) performance indicators and testosterone concentration. Ten soccer players performed three YoYoIE2 (counterbalanced crossover) wearing colorless (control), blue- or red-lensed glasses (2–4 days of rest in between). YoYoIE2 performance did not differ among the trials ($p>0.05$), but blood testosterone increased post-exercise in red compared to red baseline (red = 14 %, effect size = 0.75). Analysis showed faster heart rate recovery ($p<0.05$) at 1 min post-test for blue compared to red lenses. Rating of perceived exertion and blood lactate concentration did not differ ($p>0.05$) among the trials. Wearing red-colored lenses during high-intensity intermittent exercise increased testosterone concentration, but do not influence performance.

Introduction

Minimal gains can determine success in sports/exercise performance [29], one reason why researchers have studied several different strategies like proper diet [23], pre-exercise interventions [21, 37–40], additional training methods [10, 42], garments [15] among others. Except for visual impairment, various colors are commonplace as part of everyday human life (e. g., traffic lights, billboards, commercial business signs). Similarly, the environment surrounding sports competitors is colorful as well (e. g., uniforms, clothing of spectators). Despite this abundant prevalence of color, the influence of color on human physical performance is unclear.

Hill & Barton (2005) associated wearing the color red with success in combat sports (i. e., higher possibility of winning in wearing red garment). The authors hypothesized that wearing red could enhance the testosterone response and thereby improve performance [28]. However this testosterone hypothesis was derived from animal-based research [1, 48], and furthermore, Hill & Barton (2005) did not measure testosterone in their study. An active choice of red by individuals with high testosterone levels in a cognitive stressor test was found suggesting a link in a competitive environment. Nevertheless, the authors did not measure exercise performance data [17]. Hackney examined the testosterone responses of 10 men to a single maximum incremental exercise test (cycle ergometry) to determine the influence of red color on hormonal response and performance. He found no effects on power output, oxygen consumption, the rate of perceived exertion or testosterone concentration [26].

The rationale of these studies [17, 26, 28] was that "being or wearing red" could affect opponents' perceptions of red competitors as being of high quality. A body of research in this area has considered soccer performance and reported equivocal results. For example, soccer goalkeepers reported more positive percieved characterstics facing a penalty taker wearing a red compared to a white shirt [24], whereas penalty takers facing a goalkeeper wearing red scored fewer penalty kicks compared to when facing a goalkeeper wearing blue or green [25]. Another study reviewed the success of English soccer teams wearing red and reported greater success compared to other colors over a 55-year period [2]. However, García-Rubio, et al. [20] detailed that the same was not true for Spanish soccer teams. Other authors suggested that some of the effect of color on performance might relate to percpetual distortion caused by moving objects. To test this hypothesis, they assessed participants playing a computer game where they were trying to hit, escape from or outmaneuver certain objects of specific color. Their results suggested that red objects were easier to hit than other colors, but there were no differences in avoidance of objects of specific color [50].

Perhaps an alternative way to accurately test color effects on performance is to perform the tests in a colorful surrounding environment. In this sense, only one study has evaluated endurance performance in randomized trials using different goggles (colored lenses) and found that the color blue improved performance [19]. Although Fisher et al. [19] performed a well-controlled study, they also had no physiological measurement. In their study [19] the colors of blue and red were chosen because of their relationship at contrasting frequencies and wavelengths (e. g., red, ~450 THz and ~660 nm, respectively) and blue, (~640 THz and ~470 nm, respectively). Although the authors hypothesized that the blue might have a calming effect and the red an increased arousal level, the authors reported that the blue color condition improved muscular endurance performance compared only to the control condition (i. e., not greater than the red condition). As such, they could not explain the reason behind "blue color" ergogenic effect.

No study has investigated the effects of different colors on specific physiological tests related to team sports performance, and specificity is fundamental for sports performance [43]. For example, the YoYo intermittent endurance test level 2 (YoYoIE2) is reproducible and highly correlated to high-intensity running performance in soccer matches [5]. Because high-intensity exercise generates higher biological stress [31] and YoYoIE2 produces maximal responses for different levels of fitness [4, 33, 35], the YoYoIE2 could be a model to investigate specific performance concomitantly with biomarker responses to colors.

There is a connection between higher testosterone concentration and better human performance [9, 22] and improved muscle function [16, 32]. Also, the color red is associated with higher testosterone [17] and physiological arousal level [51], but it is unknown if a surrounding red environment can influence testosterone concentration and exercise performance. Thus, we evaluated the acute effect of wearing colored-lens glasses on YoYoIE2 performance, testosterone concentration, and other physiological indicators. We hypothesized that glasses with red lenses would increase both the testosterone concentration and exercise performance.

Methods

General procedures and experimental design

The local Ethical Committee for Human Experiments approved the current research accordingly [27], and the participants signed an informed consent form before the procedures. The participants attended the laboratory four times (2 to 4 days in between). On the first visit a screening, anthropometric measurements, and familiarization with the procedures (i. e., tried the googles and received explanations) were performed. Participants presented a medical statement confirming they did not have any eye disease and could view the colors correctly. Additional exclusion criteria included anyone using ergogenic or androgenic anabolic steroids or incapable of performing the tests proposed.

On the other three visits, the participants performed in a counterbalanced manner the YoYoIE2 test (indoor sports court, 26 ± 2 °C, humidity = 50 ± 4 %) using protective goggles. The participants were invited to abstain from strenuous physical activity for at least 48 h before sessions and from food and caffeine intake for at least 3 and 12 h, respectively, before all sessions [13, 14, 41]. All test sessions were performed between 3 and 4 p.m. (standardized for each) and conducted by the same experienced researcher.

Participants

Based on previous research [5] and the within-participants design, a sample size between 6 and 9 participants was sufficient to detect a significant ($p < 0.05$) difference among soccer playing positions ("group") in the YoYoIE2. To counteract any dropout, a sample of 10 male amateur soccer players ([mean ± SD] 21 ± 1.1 years, 1.75 ± 0.05 m, 71.9 ± 9.8 kg, 11 % ± 3 body fat, playing experience 13 ± 2 years) participated in the current study.

Protective goggles and sports court illuminance

The players performed the YoYoIE2 test wearing protective goggles (HDE®, Germany): blue lenses (wavelength 470 nm), red lenses (wavelength 660 nm) and clear lenses (no protection wavelength, "sham"). No players reported discomfort or had an issue with the glasses falling off during the strenuous exercise. The sports court illuminance was recorded on each test day using a lux meter (Gama scientific®, Landsberg am Lech, Germany).

Perceived recovery status

To ensure the participants were in the same recovery condition before each trial, all volunteers indicated a score on a perceived recovery scale [34]. The scale ranged from 0 ("very poorly recovered, extremely tired") to 10 ("very well recovered, highly energetic") in arbitrary units (AU) to rate their relative physical recovery. If the player scored 4 or less (somewhat recovered) for his recovery status, he was excluded from the day's session and was invited to return on another day.

Blood samples for testosterone

Before and 30 min after each YoYoIE2, venous blood samples (5 mL) were collected by a technician (median cubital vein) for testosterone analysis. Testosterone level was quantified in duplicate by electrochemiluminescence immunoassay (COBAS 6000 analyzers series, Roche Diagnostics Ltd., Rotkreuz, Switzerland).

YoYo intermittent endurance test level 2 (YoYoIE2)

All players were familiar with the YoYoIE2. Before the test, players performed a warm-up consisting of the first three running bouts of the YoYoIE2 test followed by a period of lower-extremity stretching. The YoYoIE2 test consists of a repeated 2 × 20- m shuttle run at progressively increasing speed stages (initial speed ~12 km.h^{-1}), guided by specific audio signals (5 s to recovery in a marked 2.5 × 2- m area after the finishing line). Cessation of the test was assessed by failure to reach the finish line by the tone on two occasions [5]. Total distance covered was recorded. The volunteers performed the YoYoIE2 test individually, and they received similar verbal encouragement during the tests. To prevent placebo/nocebo effect, a potential issue in ergogenic aids studies [11, 36, 37, 39], we informed the volunteers that all protective goggles could improve performance and none of them could be harmful. Also, we kept the participants blinded to data; i. e., no information about distance covered (the audio of speed and level of YoYoIE2 was in an unknown language), HR and blood lactate [35].

Heart rate, the rate of perceived exertion, and blood lactate concentration

The heart rate (HR) was monitored (Polar® RS800CX, Helsinki, Finland) throughout the entire YoYoIE2. After the YoYoIE2, the participants remained seated wearing the goggles for HR recording (recovery). Just after the YoYoIE2, the player indicated (individually to prevent bias) a score for his rate of perceived exertion (RPE) via the Borg CR10 scale ranging from 0 ("nothing at all") to 10 ("very very hard") to determine the internal intensity of the session [3]. In the 3rd minute after the test, a blood sample (25 µL) was collected from the fingertip to measure the lactate concentration using a valid [18] portable analyzer (ROCHE® Accu-Check, Basel, Switzerland).

Data analysis

The Shapiro-Wilk test was applied to verify the data's normality of distribution. We did a repeated measures one-way analysis of variance (ANOVA) for within-participants analysis (parametric) or Friedman test (nonparametric data), with Tukey and Dunn tests as post-hoc tests. The effect sizes (Cohen's d) were calculated to determine the magnitude of practical relevance (only for significant, i. e., α value of ≤ 0.05 result) and were interpreted as small (0.2), medium (0.5) and large (0.8), as suggested [6]. For the testosterone values (pre- and postcondition in each trial), a two-way ANOVA was conducted followed by Sidak's post-test. Data are presented as mean ± SD.

Results

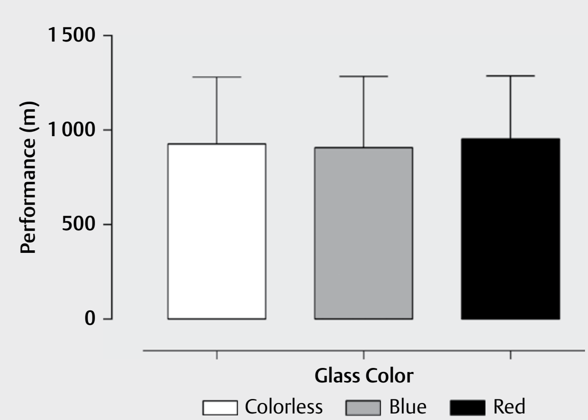
The illuminance of the sports court was similar (Friedman test, p = 0.1) for each of the three conditions (~101 lux). The score on the perceived recovery scale before each trial also did not differ (Friedman test, p = 0.9) among the three trials (colorless: 7.5 ± 1.5 AU; blue: 6.8 ± 2.4 AU; red: 7.0 ± 1.9 AU).

The distance covered in the YoYoIE2 performance did not differ (ANOVA, p = 0.7) among the three trials (▶ **Fig. 1**) and the players covered ~930 m (mean of three trials). The rating of perceived exertion immediately after the YoYoIE2 also did not differ (Friedman test, p = 0.99) among conditions: control 8.6 ± 1.2 AU; blue: 8.7 ± 1.3 AU and red: 8.4 ± 1.3 AU.

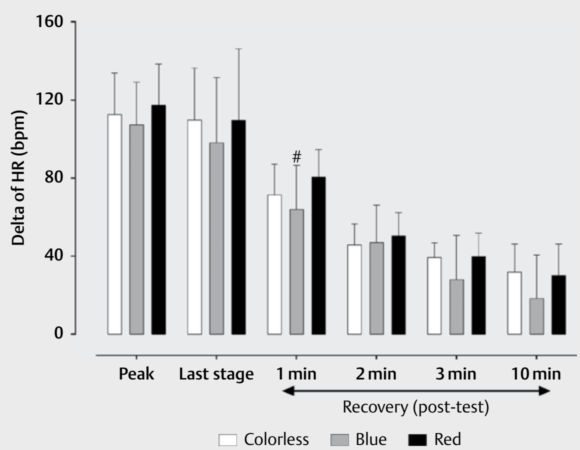
Relative HR (% of maximum) during the exercise did not differ (p > 0.05) among trials (ANOVA, $\%HR_{max}$: control: 95 ± 6; blue: 92 ± 7; red: 97 ± 6). The delta HR values (difference between resting HR and during the analyzed time) was significantly different among conditions (ANOVA, p < 0.05, effect size 0.89) in the 1st minute post-test (lower in blue than red glasses – ▶ **Fig. 2**).

In relation to the baseline values (delta: post – pre YoYoIE2), following the red-lensed condition testosterone concentration increased by ~14 ± 7 %, which was higher (Friedman test, p = 0.01, effect sizes 0.95 and 0.56, respectively) than colorless (0.9 ± 2 %) and blue lenses (5 ± 3 %). The absolute testosterone concentration was elevated (two-way ANOVA, p < 0.05, effect size = 0.75) in relation to the baseline values after the red-lensed condition, but no differences were found (p > 0.05) in either the control or blue-lensed conditions (▶ **Fig. 3**).

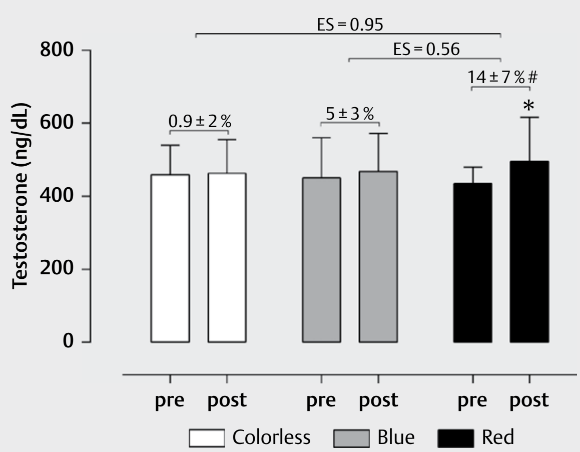
The blood lactate concentrations (measured 3 min post-test) did not differ (ANOVA, p = 0.21) among conditions (colorless: 10.2 ± 1.2 mmol/L; blue: 9.9 ± 4.1 mmol/L; red: 8.6 ± 3.1 mmol/L).



▶ **Fig. 1** Distance covered (m) for YoYoIE2 in each color condition. Values are mean ± SD.



▶ **Fig. 2** Delta of hear rate (HR) difference between resting HR and during the analyzed time. # p < 0.05 in comparison with red lenses. Values are mean ± SD.



▶ **Fig. 3** Absolute blood testosterone levels pre- and post-YoYoIE2 for each color condition. Values are mean ± SD; * means p < 0.05 vs pre-test (effect size = 0.75). The percentage numbers above the bars are delta (% difference between post – pre values); # red lensed condition higher (p = 0.01) than both other conditions; ES = effect sizes.

Discussion

This study is the first to test the acute effects of wearing glasses with colored lenses on high-intensity intermittent exercise performance and metabolic responses. It is also the only study to explore the effect of colors on exercise performance while controlling for ambient illuminance and recovery status of the participants, both of which are fundamental to rigorous research design. Our main findings were that colored lenses did not influence YoYoIE2 performance (distance covered); however, the red-lensed condition showed increased blood testosterone concentration. The lack of effect of the color on physical performance is in contrast with previous research [8, 19, 44]. This discrepancy is likely a result of the type of exercise.

The YoYoIE2 represents a high-intensity exercise demanding near maximum physiological indicators. For example, a study showed responses of heart rate of ~99 % of maximum, blood lactate ~10 mmol/L, decrements of ~24 % in muscle glycogen and ~70 % muscle phosphocreatine in non-elite practitioners [33]. Besides, the YoYoIE2 is highly specific to soccer demands, including changes of direction and acceleration/deceleration, which are inherent to soccer performance and thus appropriate for checking ergogenic effects. Previous research about color and performance has assessed strength and power outcomes. For instance, Fisher et al. showed that wearing blue-lensed glasses (compared to red or colorless) improved endurance performance in leg press resistance exercise in young healthy males [19]. In contrast, a room with red lighting (compared to blue or white light) improved performance in a Wingate anaerobic power test, whereas a room with white light produced greater handgrip strength test [8]. However, in other research college students exhibited greater grip strength in the presence of red visual stimulation (compared to green) [44]. Notably, none of those above studies measured potentially mechanistic physiological variables such as testosterone and so comparison to the present research is impossible.

Our data supported that the YoYoIE2 promoted maximal effort by the participants (e. g., the rate of perceived exertion > 8 on a scale 0–10 and 92–97 % of HR_{max}) during the three trials, which is appropriate because the YoYoIE2 is considered a maximal-intensity exercise. The distance covered in the current study (~ 930 ± 355 m - mean of the trials) was higher than untrained individuals (665 ± 271 m) but lower than trained (2027 ± 298 m) soccer players [33]. Because our sample included young, amateur soccer players, our results are in agreement with the previous literature [35].

Our HR % values are similar to those reported in previous research on elite under 19-year-old soccer players (~94.5 % ± 6.8) [5]. Also, the absence of differences among color trials in perceived exertion (maximal effort) is consistent with previous research [19].

We found lower delta HR values for the color blue in comparison to red in the first minute of recovery after YoYoIE2. Although Fisher et al. (2015) reported similar HR values for red, blue and colorless conditions, they did not record HR during recovery. Furthermore, because the present study tested high-intensity intermittent exercise rather than a resistance exercise task, comparisons with similar research is not possible. However, there is tenuous support for an increase in parasympathetic activity, which might serve to reduce HR faster. Authors reported that using a blue partition board reduced task-induced subjective fatigue, possibly by increasing autonomic reactivity [47]. Thus, we speculate that within the present study there was an influence of the blue color on the autonomic nervous system (i. e., increasing parasympathetic activity), reducing HR faster post-exercise. In fact, the blue color has been associated with activation of the parasympathetic nervous system, reducing heart rate [30]. From a practical application, a faster recovery following high-intensity exercise could be beneficial for several sports. Future studies measuring parasympathetic and sympathetic activities could check for possible adaptive effects of long-term training with the use of blue-lensed glasses on HR response. Within our study, there were no statistical differences for

HR delta 2, 3, and 10 min post-test, suggesting that autonomic activity had already affected the reduction in HR (i. e., blue-lensed glasses had no continued effect).

We found that the red color-lensed condition resulted in increased blood testosterone concentration post-test, advancing the understanding of the previous research that associated wearing red with better performance [28] or active choice of red with higher basal testosterone levels [17]. This was in contrast to the blue-lensed (effect size 0.56 - medium) and control-lensed (effect size 0.95 - large) conditions. The large effect size found could be promising for practical application, once studies have associated performance and testosterone [7, 22, 46]. However, the present study does not confirm such a positive relationship because YoYoIE2 performance was not improved. Maybe the nature of YoYoIE2, i. e., intermittent maximal test, including acceleration/deceleration, changes of direction, eccentric actions involved, might counterbalance the acute effect of higher testosterone. Future studies could investigate whether this testosterone increase could positively influence performance later in the same day, as others have found for power exercises [7]. Furthermore, because the use of red-lensed glasses during chronic exercise (i. e., physical training) has not been evaluated to date, future research should consider specific cases where elevated testosterone levels might be beneficial. For instance, a study involving 2587 men (aged 65 to 99 years) showed that fall risk was higher in men with lower bioavailable testosterone levels “independent” of physical performance [45].

The blood lactate concentration did not differ among conditions. Although no previous study has evaluated the effects of color on post-exercise blood lactate, the similar results among colors make sense because blood lactate is related to the intensity of exercise, and we did not find differences among colors in the distance covered, HR% or rate of perceived exertion. Furthermore, the post-test values of ~10 mmol/L resemble those found in another study [33].

As limitations of the present study, we could highlight: the absence of measurements to explain the mechanisms underpinning increased testosterone levels for red lenses (e. g., light perception, retinohypothalamic pathway), and the accurate measure of parasympathetic activation to check the effect of blue lenses on HR recovery. The sample size was relatively small (n = 10) and could generate a type II error and does not permit playing position comparisons that would be appropriate for soccer [12, 49]. Another potential limitation could be related to the lack of a non-exercising control condition. However, we used a crossover design (including blood samples collected before and after each condition) to minimize these limitations. Additionally, our study adds to our understanding of the association among color, human performance, and related indicators.

In summary, our results suggest that (acute) wearing colored lenses does not influence high-intensity intermittent exercise performance and internal intensity indicators (rate of perceived exertion and HR responses) in amateur soccer players. However, wearing red-colored lenses during high-intensity intermittent exercise increases testosterone concentration after the session, and blue color seems to increase parasympathetic activity, improving HR recovery.

Conflicts of Interest

The authors declare that they have no conflict of interest

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