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Original Article

Negative effects of smartphone use on physical and technical performance of young footballers

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Abstract:
Mobile devices (i.e., smartphones and tablets) have acquired important functions in both interpersonal and individual spheres. For this reason, they can cause a true dependence for the young people. The purpose of this study was to assess the effects of prolonged use of smartphones on physical and technical performance of young footballers. In total, 16 young male footballers (15.0 ± 1.1 years) were randomly assigned to two studies, Study 1 (S1, n=8) or Study 2 (S2, n=8), in which the Yo-Yo Intermittent Recovery Test level 1 and the Loughborough Soccer Passing Test were performed, respectively. The soccer-specific physical and technical performance was assessed for S1 and S2. In both studies, the participants underwent to mental fatigue through the use of smartphones (Brain It On App) for 30 minutes, and to the control condition (normal activities) after at least 48 hours. S1 performed shorter running distances in the state of mental fatigue than under the control condition (Δ -10.56%; p = 0.046; d = 0.82). In addition, mental fatigue significantly increased the performance time in S2 compared with the control condition (Δ +15.7%; p = 0.003; d = 1.64). Our findings suggest that prolonged use of smartphones, which causes mental fatigue, can reduce the physical and technical performance of young footballers. Therefore, it is necessary to educate to the conscientious use of technology.
Key words: mental fatigue; cognitive task; physical education; technology.

Introduction

Mobile devices, such as smartphones and tablets, are a filter through which the reality and interpersonal relations are enjoyed. These devices have acquired important functions in both interpersonal and individual spheres. Because these objects are status symbols that are strongly tied to fashion, they can cause a true dependence for the adolescents. In Italy, 17 % of young people cannot stop using smartphones and social networks, 25 % are always online, 45 % are connected several times a day, 78 % chat continuously on WhatsApp and 21 % are afflicted by vamping, which means that they wake up during the night to check messages on their cellphones (Safer Internet Day, 2016). Besides, the brightness of devices can delay sleep of those who use them for a long time before sleeping (Figueiro, Wood, Guilty, and Plitnick, 2012). In the field of physical education, the use of these devices to play, for example, videogames has often been viewed with skepticism and has been traditionally associated with several risks to physical and mental health (Funk & Buchman, 1995). When significant effort is focused on cognitive exercise, there is a possibility of mental fatigue (Kaplan, 2001). Recent studies have demonstrated that mental tasks that involve cognitive control can lead to the reduction of systemic glucose. This indicates that a significant mental effort can produce a state of tiredness that can influence performance (Gailliot & Baumeister, 2007).

Previous studies, which observed the effects of mental fatigue on physical performance, demonstrated that prolonged periods of cognitive activity induce mental fatigue, which is a psychological state that is characterized by tiredness and lack of energy (Boksem, Meijman, & Lorist, 2006; Marcora, Staiano, & Manning, 2009). Besides, it has been suggested that mental fatigue can negatively impact on explosive strength, maximum muscular contraction, power and anaerobic work capacities (Ferraz et al., 2011; Martin, Thompson, Keegan, Ball, & Rattray, 2015; Pageaux, Marcora, & Lepers, 2013; Rampinini, Impellizzeri, Chestnut, Coutts, & Wisloff, 2009; Smith, Marcora, & Coutts, 2015). Furthermore, mental fatigue affects performance during constant weight resistance testing (Marcora et al., 2009). Team sports are characterized by very important cognitive requests that force athletes to maintain concentration for prolonged periods of time and to take swift and accurate decisions in a highly dynamic environment (Montgomery et al., 2008; Tavares, Smith, & Driller, 2017; Walsh, 2014). In fact, the study by Smith et al. (2016b) indicated that mental fatigue induced by a cognitive task of 30 minutes increased decision-making time and reduced accuracy of tired players compared with a control group during game situations that were created during Small Sided Games. Additional studies highlighted a decrease in terms of quantity and quality of technical performance due to mental fatigue, which was verified by the competition progress (Carling & Dupont, 2011; Rampinini et al., 2008, 2009).

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The studies highlighted that the condition of mental fatigue is induced by long and intense cognitive tasks, which lead to an objective feeling of tiredness and lack of energy. To identify the standardized conditions of mental fatigue, cognitive tasks are provided using a personal computer. These tasks include Psychomotor Vigilance Task (Loh, Lamond, Dorrian, Roach, & Dawson, 2004), Ax-Continuous Performance Task (Smith et al., 2015), and Stroop Color Task (Smith et al., 2016a). While trying to clarify neurological mechanisms that are at the base of the relation between mental fatigue, perception of fatigue and performance, it is still necessary to take into account real habits of athletes during pre-competition or pre-training. In fact, even if the athletes can devote themselves to mentally hard tasks before a game, it is improbable that before the competition they perform a similar cognitive task, for example "Stroop color". Therefore, the present social habits of prolonged use of smartphone or tablet should have been identified. In this respect, there are no studies in the literature that evaluate the effects of these electronic devices, and little is known about the fatigue that they can induce in young footballers. Thus, the present research aims to investigate the effect of prolonged use of smartphones on the physical and technical performance of young footballers. It was hypothesized that the prolonged device utilization during pre-competition induces mental fatigue, which limits both the physical performance and technique.

Material and methods

Participants

Sixteen young healthy male footballers (15.0 ± 1.1 years old; height 1.71 ± 0.1 m; weight 61.4 ± 8.2 kg; BMI 20.9 ± kg/m2) participated voluntarily in this study. The participants were recruited from the youth sector of the ASD Nick Calcio Bari in April 2017, and subsequently they were assigned randomly to two groups. One group participated in Study 1 (n=8), and another group participated in Study 2 (n=8). Randomization was achieved using a software that is available online (www.randomization.com). All of the participants and their parents received complete information about the experiment and gave their agreement. The ethical principles based on the declaration of Helsinki were respected in the research. The study was conducted in May 2017.

Procedures

A cross-over design in which the same group was subjected to the experimental condition and control condition was used for both studies. Each group was subjected to the condition of "mental fatigue" and to the condition of "control", separated by a minimum of 48 h. The sessions of control and mental fatigue were performed in a randomized and counterbalanced order generated by online software (randomization.com). Before starting the study, the subjects were informed about the evaluations and procedures. The players did not perform any activities during 48 hours before the evaluation sessions. The participants completed all testing sessions at the same time of day (within 1 h), starting at 15:30. Besides, all of the measurements were carried out by the same person who has a degree in motor sciences, and standardized test protocols were used under his supervision. This research was planned to estimate whether the use of smartphones for 30 minutes with a free application named "Brain It On" was able to cause any possible performance decrease during the evaluation of physical (study 1: Yo-Yo Intermittent Recovery Test level 1) and technique (study 2: Loughborough Soccer Passing Test) performance of young footballers.

Performance testing

Yo-Yo Intermittent Recovery Test level 1 (Yo-Yo IR1). It is a valid and reliable test of physical performance for football players (Bangsbo, Iaia, & Krustrup, 2008; Krustrup et al., 2003). It is an evolution of the Lèger test (20-m shuttle run test), and this test was proposed to make the execution protocol closer to a real football competition, inserting a pause of 10 seconds after each shuttle (2 × 20 m) (Figure 1)

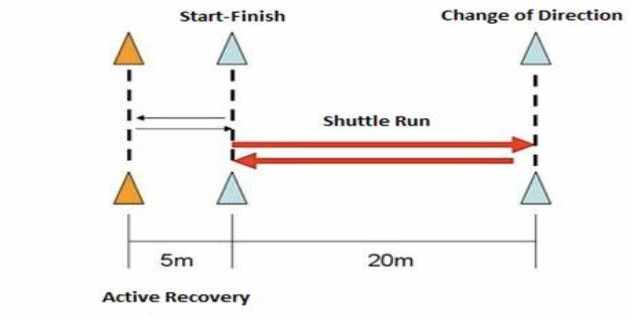

Fig. 1 - Schematic representation of the run used to make the Yo-Yo Intermittent Recovery Test level 1.

The test consists of running 20 m with a progressively increasing speed and with intervals of 10 seconds of active and continuous recovery up to the time when the players are able to hold the rhythm with a speed dictated by an acoustic signal. The distance completed up to that moment is noted in the final test. The test is

preceded by a short warm-up. The test starts at 10 km/h. The rhythm and the increase of the speed of the run are regulated using an audio signal. It is a maximal intermittent test with a change of the running direction, and it can be given to many players at the same time. It has high reliability and allows to make a detailed analysis of physical abilities of athletes in intermittent sports. During the test, the aerobic intensity approaches maximum values, and the anaerobic energy system is kept very busy (Krustrup et al., 2003). The Yo-Yo Intermittent Recovery tests provide a simple and valid way for obtaining important information about the ability of an individual to repeatedly carry out intense exercises and to examine changes in the performance (Bangsbo et al., 2008). In addition, the tests show their validity for elite football players (Fanchini, 2015), and they are reliable for evaluating performance of young footballers (Póvoas et al., 2016). At the end, Yo-Yo IR1 shows a strong correlation between the obtained result and athletic performance.

Loughborough Soccer Passing Test (LSPT). To evaluate the specific technical performance in football and to quantify the skill of footballers to make short passes, the first version of LSPT test was used, which was developed and validated by Wings et al. (2003). The schematic representation of the run used in the test is shown in figure 2.

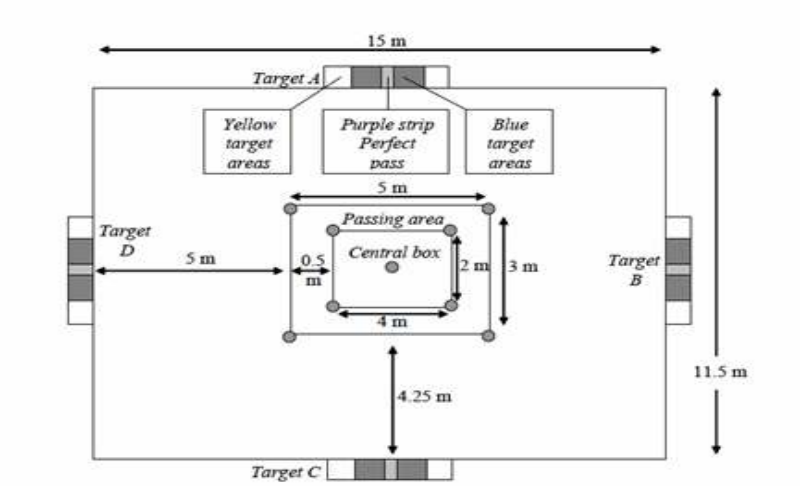

Fig. 2 - Schematic representation of the run used for the Loughborough Soccer Passing Test.

The test consists of the execution of 16 passages clockwise that are made within a run as fast and exact as possible. Four targets with a dimension of 30 × 60 cm (two yellow and two blue targets) and one target with a dimension of 30 × 10 cm (purple) were positioned on a wooden target (30 × 250 cm). The subjects start with the ball in the central box and, after the signal of the operator, they must lead the ball to the passing area, make the pass towards the target A, retake the control of the ball, return with the ball to the central box and then move in the direction of the target B using the same approach. Then, before making the next passage in the passing area, the ball must be led to the central box. According to the errors made by the athletes, the following penalties are provided:

- + 5 s to completely miss a target or to hit a wrong target with the ball;
- + 3 s to hit the wooden target but miss the colored targets (for example, to hit a corner of the wooden target);
- + 2 s to hit a yellow target;
- + 1 s to hit a blue target;
- + 2 s to make the passage to the outside of the passing area;
- + 2 s if the ball touches a cone;
- +1 s for each second over 43 ", which is a pre-established time to complete the test.

For each passage that perfectly strikes the purple target, 1 second from the total time is taken away.
There are three performance indices:

1) required total time to complete 16 passages and to return to the central box (LSPT time);
2) accumulated penalties (LSPT penalties);
3) sum of these first two indices as an indicator of total performance (LSPT total).

Experimental conditions

Condition of mental fatigue. The participants drew figures on the smartphone screen to solve puzzles, which were proposed by free application "Brain It On", with the fastest solution to advance to the next level. To increase the motivation for the activity, a competitive environment was created. Therefore, the participants challenged each other to complete successfully as many levels as possible within 30 minutes. The participants from both groups completed the task in the same room under the supervision of the same researcher.

Condition of control. The participants carried out their usual activities before the training.

Study 1

During the first meeting, standardized instructions were supplied to the participants to be memorized and to use the Borg scale for the subjective perception of the exertion CR10 (RPE) (Borg, 1998). The participants had an opportunity to learn the Yo-Yo IR1 (Bangsbo et al., 2008), and they were instructed to avoid vigorous activities the day before the next visit and to consume a light meal 2 hours before the test. The respect for these instructions was estimated using a pre-test checklist on arrival. Still, the respect for these instructions was not evaluated using objective measures. The RPE values were recorded at the end of each Yo-Yo IR1 level and also at the point of exhaustion (10 minutes prior to the end of the test). For both conditions, the participants were asked to perform the test to exhaustion. Besides, no motivational intervention was supplied beforehand or during the Yo-Yo IR1. During the "control" session and during the "mental fatigue" session, the participants had 2 minutes of warm up before the test.

Study 2

The participants were familiarized with LSPT twice (Ali et al., 2003). They were given the same pre-test instructions as the study 1 participants, and the conformity was ensured via a pre-test checklist at the moment of arrival for the test sessions. The control and mental fatigue sessions in study 2 followed the same procedures as in study 1 up to the warm up phase. For Study 2, 2 minutes of warm up with a ball with elements of passage, dribbling and ball control were carried out. After the warm up, the participants completed the technical test. No motivational intervention was made before or during the tests of specific football skills.

Statistical analysis

All data are presented as mean ± SD and statistically analyzed using the software SAS JMP version 13.2 (Cary, NC, USA). To compare between the two conditions to which the groups were subjected, one-tailed Student's t-test for the dependent samples was used. Besides, to estimate the scientific magnitude of the differences within the groups, the effect size d was calculated using the formula of Dunlap, Curtain, Vaslow and Burke (1996) and interpreted according to Cohen (1988), with the values of 0.20, 0.50 and 0.80, which indicate a small, medium and large effect size. The statistical significance was set at $p<0.05$.

Results

Study 1

Yo-Yo Intermittent Recovery Test level 1. Figure 3 shows the mean distance completed during the Yo-Yo IR1 test. The participants completed shorter distances under the condition of mental fatigue compared with the control condition (1610 ± 135 m vs. 1780 ± 249 m; Δ -10.56%; t = -1.95; p = 0.0460; d = 0.82).

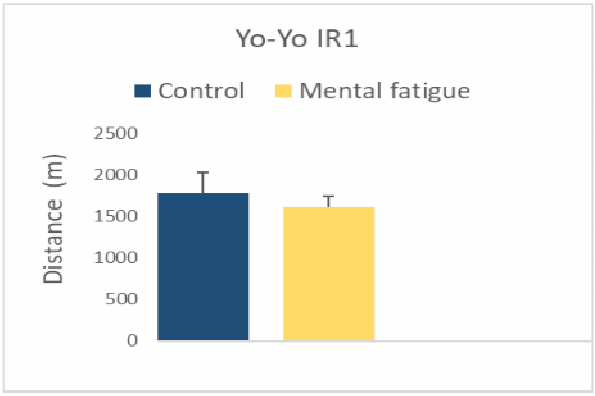

Fig. 3 - Effect of mental fatigue during the Yo-Yo Intermittent Recovery Test level 1. The data are shown as mean ± SD. The difference is statistically significant (p < 0,05).

Subjective perception of the exertion. Statistically significant differences were not observed ($p > 0.05$) with regard to the subjective perception of the exertion using the Borg CR10 scale between the condition of mental fatigue (RPE = 7.9 ± 0.35) and of the control (RPE = 7.1 ± 1); for both conditions, perception of the exertion at the end of the test was very strong.

Study 2

Loughborough Soccer Passing Test. The ability of making passes was affected by the mental fatigue. The score, statistical differences and their scientific magnitude are shown in table 1.

Table 1 – Effects of the mental fatigue on the soccer-specific technical performance evaluated using the Loughborough Soccer Passing Test.

LSPT	CONTROL	MENTAL FATIGUE	p	d
Original time (s)	40.1 ± 3.4	42 ± 3	0.0221	0.57
Penalty time (s)	2.9 ± 2.2	9 ± 4,5	0.0105	1.11

Performance time (s)	43 ± 2.2	51 ± 6	0.0030	1.64

A statistically significant difference was found between the two conditions in "Performance Time" (Δ +15.7%; t = - 3.89; p = 0.0030; d = 1.64) (Figure 4). The "Penalty Time" was significantly greater for the mental fatigue condition compared with the control condition (t = - 2.96; p = 0.0105; d = 1.11). This indicated that the participants were less accurate under the mental fatigue condition.

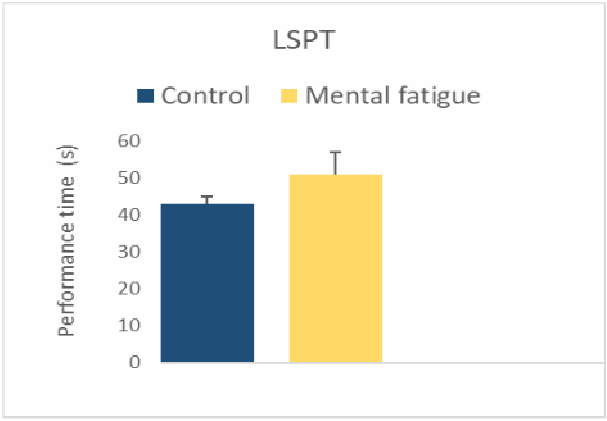

Fig. 4 – Effect of the mental fatigue on "Performance time" during the Loughborough Soccer Passing Test. The data are shown as mean ± SD. The difference is statistically significant (p<0.05).

Discussion and conclusions

The purpose of the present research was to investigate the effects of the prolonged use of smartphones on the physical and technical performance of young footballers. The results confirmed our hypotheses. Specifically, the participants completed shorter distances during the intermittent run that simulates the requirement of a team sport, such as football, made more mistakes during the passes, and control of the ball was less accurate after being mentally fatigued.

In the first study, Yo-Yo Intermittent Recovery Test level 1 was used, and the evident result is the decrease of physical performance of the footballers, following the inducing fatigue, in accordance with previous studies (Ferraz et al., 2011; Martin et al., 2015; Pageaux et al., 2013; Rampinini et al., 2009; Smith et al., 2015). In fact, the prolonged use of a smartphone probably induced a mental fatigue, reducing the completed distance to 170-m, with an individual mean decrease of 10.56 %. This confirms that the reduction of physical performance, which happened in the present research, is similar to that induced via the Stroop Color test used by Smith et al. (2016a), which recorded 207 meters of the distance completed, with an individual mean decrease of 16.3 %. Then, it is possible to state that mental fatigue modifies the intermittent exercise in the test that simulates the requirements of a team sport, as asserted by Smith et al. (2015), and, probably, it can significantly affect high-intensity running performance during a game (Krustrup et al., 2003).

Although the perception increase of the exertion is mostly responsible for the negative effects of mental fatigue on effort tolerance (Pageaux et al., 2013; Smith et al., 2016a), in this study, the condition of mental fatigue has not determined a greater subjective perception of the exertion using the Borg CR10 scale, in disagreement with the results of the study by Smith et al. (2016a). Nevertheless, the participants stopped earlier compared with the control condition and completed smaller total distance, as in the studies by Smith et al. (2015, 2016).

The purpose of the second study was to analyze the technique of execution of the fundamental football movements using the Loughborough Soccer Passing Test. The results confirmed that the prolonged use of smartphones causes mental fatigue and may increase the number of passages and ball controlling errors, which can reduce the quality and quantity of the technical performance, as it happens at the end of a football match (Rampinini et al., 2009). Besides, the results of the present study agree with some studies that evaluated the effects of mental fatigue on the technical performance of footballers using different protocols (Rampinini et al., 2008; Smith et al., 2016a). In addition, the results agree with studies from other fields of research, which highlighted an increase in errors due to the mental fatigue during cognitive tasks and driving tasks (Boksem et al., 2005; Gailliot & Baumeister, 2007; Kaplan, 2001; Lal & Craig, 2001).

The present research shows some limitations, which should be considered during the interpretation of the results. In fact, due to the reduced sample size, the results of the study should be interpreted with caution. Besides, during the first study, physiological parameters were not measured, such as cardiac frequency, hematic lactate, and arterial pressure, which could have supplied additional evidence about the effects of prolonged use of smartphones and the induced mental fatigue.

However, this is the first study that examined the influence of prolonged use of smartphones, via a "game application", on the physical and technical performance of young footballers. The real need to identify

common and habitual pre-competition activities that can induce mental fatigue, allowed to develop research using a widely used electronic device instead of a cognitive task, such as the Stroop color, which simulates an unrealistic pre-competition tasks. In the future, it will be interesting to verify the effects in other sports and, if possible, to compare the effects caused by a smartphone or a tablet with the laboratory cognitive tests. Finally, our findings confirm that the sustained mental effort, as when a smartphone is used for playing, can induce mental fatigue and limit performance. Thus, it is evident that present social need is to educate the youth to use technology conscientiously.

Authors' contribution

Gianpiero Greco contributed to research conception and design, data analysis and interpretation, writing and critical review of the manuscript. Roberto Tambolini contributed to research design, data acquisition and interpretation. Pasquale Ambruosi contributed to research design and data interpretation. Francesco Fischetti coordinated the study and contributed to research design and critical review of the manuscript. All authors have read and approved the final manuscript.

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