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Effect of Low Dose Caffeine Ingestion on 8000–m Roller Skiing Performance

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Abstract
The aim of the study was to investigate the effect of relatively small caffeine dose (~3 mg·kg^{-1}) ingestion on 8000-m roller skiing time trial performance and heart rate (HR). The volunteers participating in the present study were 9 female elite roller skiers with 16-19 years of age, the body weight of 55.3 ± 6.4 kg, the height of 164.2±3.7 cm, and a body mass index of 20.4 ± 1.8 kg/m^2. The experiment was a randomized double-blind crossover design, which involved repeated measures of the same participants. Participants were randomly divided into 2 groups and completed 2-time trials roller skiing performance for 8000 m. 60 min before each trial, the subjects consumed 150 mg (~3 mg·kg^{-1}) caffeine (CAF) (SİS-GO ENERGY - Double Espresso) or placebo (PLA) in gel form. CAF and PLA intake were interverted between groups for the second trial. Throughout the two 8000-m time trials, 1000 m split times and total time were recorded and immediately before and after time trial performances heart rate (HR) was measured. Data were analyzed using the SPSS 26.0 software package. Normality of distribution for outcome measures was tested using the Shapiro-Wilk test and it was determined that the data showed normal distribution. Paired sample t-test was used to check possible differences between intervention. Time trial performance was not statistically significant different between CAF and PLA trials ($p>.05$). However, caffeine ingestion resulted in an average improvement of 45,23 seconds which is translated to a 2,93% improvement in performance time. Additionally, 66,6% of the participants completed 8000-m roller skiing time trial performance faster during the CAF trial compared to PLA trial. After the HR results examination, it was seen that pre-test HR as well as post-test HR were not statistically significant different between trials. In conclusion, caffeine ingestion resulted in a total mean reduction in performance time and also did not increase HR compared to PLA. Therefore, relatively small CAF gel dose (~3 mg·kg^{-1}) might be used effectively pre-workout ergogenic aid when supplementation during the exercise is not possible.

Keywords: Caffeine, Heart rate, Roller skiing, Time trial performance

Düşük Doz Kafein Takviyesinin 8000-m Tekerlikli Kayak Perfomansına Etkisi

Özet
Bu çalışmanın amacı, düşük doz kafein (~3 mg.kg-1) kullanımının 8000-m tekerlekli kayak performans süresi ve kalp atım hızı üzerine etkisini incelemektir. Çalışmaya; 9 kadın, elit tekerlekli kayak sporcusu gönüllü olarak katılmıştır (yaş:17.4±1 yıl; vücut ağırlığı: 55.3±6.4 kg; boy: 164.2±3.7 cm; vücut kütle indeksi: 20.4±1.8 kg/m^2). Çalışmada aynı katılımcıların tekrarlanan ölçümlerini içeren, rastgele çift kör çapraz geçişli tasarım kullanılmıştır. Katılımcılar rasgele 2 gruba ayrılmış ve her bir katılımcı 4 gün arayla 2 kez zamana karşı, 8000-m tekerlekli kayak performansına dahil olmuşlardır. Her iki performanstan da 60 dk önce katılımcılara jel formunda 150 mg (~3 mg.kg-^{1}) kafein (KAF) (SİS-GO ENERGY-Double Espresso) veya plasebo (PLA)

verilmiştir. İkinci zamana karşı 8000-m tekerli kayak performansında, bir önceki performansta KAF verilen gruba PLA, PLA verilen gruba CAF takviyesi verilmiştir. 8000-m tekerlekli kayak performansı sırasında sporcuların her 1000 m'de geçiş süreleri ile toplam skorları kaydedilmiştir ve performanstan hemen önce ve hemen sonra kalp atım hızları (KAH) ölçülmüştür. Elde edilen verilerin analizde SPPS 26.0 paket programı kullanılmıştır. Bağımsız değişkenlerin dağılımı Shapiro-Wilk testi ile değerlendirilmiş ve verinin normal dağılım gösterdiği saptanmıştır. Müdahaleler arasındaki muhtemel farklılıkları tespit etmek için paired sample t-test kullanılmıştır. İstatiksel analiz sonuçlarına göre; 8000-m tekerlekli kayak performans süresinde KAF ve PLA müdahaleleri arasında istatiksel olarak anlamlı fark saptanmamıştır ($p>0.05$). Ancak; CAF takviyesi alımı, performans süresinde %2,93'lük (45.23 sn) bir iyileşme ile sonuçlanmıştır. Ek olarak, katılımcıların %66,6'sı KAF müdahalesinde, 8000-m tekerlekli kayak performansını daha kısa sürede tamamlamıştır. Ön test KAH ile son test KAH sonuçları karşılaştırıldığında müdahaleler arasında istatiksel olarak anlamlı fark saptanmamıştır ($p>0.05$). Sonuç olarak; nispeten düşük dozda KAF kullanımının istatiksel olarak anlamlı olmasa da performans süresinde iyileşme sağladığı ve aynı zamanda KAH'nda önemli bir artışa sebep olmadığı görülmüştür. Bu nedenle egzersiz sırasında ergojen alımının mümkün olmadığı durumlarda, CAF egzersiz öncesi etkili bir ergojen olarak tercih edilebilir.

Anahtar kelimeler: Kaffein, Kalp atım hızı, Tekerlekli kayak, Zamana karşı performans

INTRODUCTION

In some types of sports, such as football matches or time-trail bike races lasting less than 1 h, athletes cannot take as many supplements as they need during competition (Ivy et al., 2009) For this reason, the importance of supplements used before exercise is increasing and caffeine is one of the most frequently researched supplements as a pre-workout ergogenic aid.

There have been numerous studies and reviews indicating that caffeine ingested (3-9 $mg \cdot kg^{-1}$) 1h before exercise causes rapid and significant improvements in endurance performance such as running (Bridge & Jones, 2006), rowing (Skinner et al., 2010) and cycling (Ivy et al., 2009). The effects of caffeine most commonly reported as an ergogenic aid are an increase in oxygen consumption or an improvement in performance time. However, another group of studies reported no difference in oxygen consumption, other physiological variables, or performance time. The different results obtained in the studies can be explained by different reasons such as the caffeine form used (caffeine capsule vs caffeine gel etc.), caffeine dosage, exercise protocol or exercise intensity.

Several mechanisms have been proposed to explain why CAF consumption improves endurance performance (Graham, 2001; Tarnopolsky, 2008). At first, CAF was observed and thought to have a carbohydrate-sparing effect (Costill et al., 1978; Ivy et al., 1979). This theory, however, cannot explain enhanced performance in short-duration activities, because glycogen content is unlikely to be a limiting factor (Jenkins et al., 2008; Skinner et al., 2010). CAF's ergogenic effects have also been linked to its inhibition of adenosine receptors and enhanced motor unit recruitment (Bazzucchi et al., 2011; Burke, 2008; Doherty & Smith, 2005; Goldstein et al., 2010; Graham, 2001). Adenosine receptors are expressed in most tissues of the human body, and blocking them can impact both heart rate (HR) and rating of perceived exertion (RPE) (Bell et al., 1998; Bell & McLellan, 2002; Fredholm et al., 2001).

The ergogenic benefits of CAF have generally been demonstrated for workouts requiring leg muscular endurance (e.g., cycling, running, and rowing) during endurance performance tests lasting 10–90 minutes (Bridge & Jones, 2006; Ivy et al., 2009). However, during roller skiing, the arm muscles provide periodically the speed-generating force, and the arm muscles' endurance capacity therefore plays a critical role in the performance outcome. Arm muscles have a higher percentage of type 2 fibers, extract less oxygen, and rely more on carbohydrate usage during exercise than leg muscles, according to research (Calbet et al., 2005; Helge, 2010; Van Hall et al., 2003). Due to observed differences between arm and leg muscles, CAF may act differently when an exercise performance is relying on endurance capacity of the leg and arm muscles (Stadheim et al., 2013).

In this context, the purpose of the present study was to investigate the effect of relatively small caffeine dose (~3 $mg \cdot kg^{-1}$) ingestion on 8000-m roller skiing time trial performance and HR.

METHODS

Participants

The volunteers participating in the present study were 10 female roller skiing athletes with 16-19 years of age, the body weight of 55.3 ± 6.4 kg, the height of 164.2±3.7 cm, and a body mass index (BMI) of 20.4 ± 1.8 kg/m^2. One participant dropped out due to private reasons; 9 participants successfully completed all performance tests and were included in the analysis. All volunteers were elite competitive roller skier. Each participant gave a written consent before the start of the study. The inclusion criterion was based on their participation for at least three consecutive years in national competitions. They were also not using any medication at the time of the research.

Trial Design

The experiment was a randomized double-blind crossover design, which involved repeated measures of the same participants. Each participant was required to complete an 8000-m race as quickly as possible while competing against each other. Subjects completed 2-time trials roller skiing performance for 8000 m, each separated by one week. After 20 min of warm-up, the roller skiers performed 8000-m time trial roller skiing performance with maximal efforts. A 4-day allowed time for subject recover from the performance. Throughout the two 8000-m time trials, 1000 m split times and total time were recorded. In addition, to examine the effect of caffeine ingestion on HR, immediately before and after the time trial performances, the HR of the participants was measured.

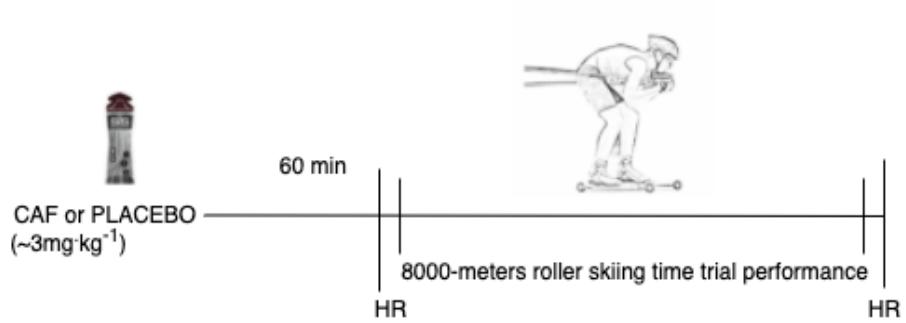

Figure 1. Trial design

Supplementation Protocol

Participants were randomly divided into 2 groups and completed 2-time trials roller skiing performance for 8000 m. 60 min before each trial, the subjects consumed 150 mg (~3 mg·kg^{-1}) CAF (SİS-GO ENERGY - Double Espresso) or PLA (SİS-GO-Isotonic) in gel form. CAF and PLA intake were interverted between groups for the second trial.

Measurement Tools

Throughout the two 8000-m time trials, 1000 m split times and total time were recorded by using digital stopwatch (CATIGA Tiga CG-503). HR measurements before and after the performance were measured with a heart rate monitor (Polar H10 heart rate sensor).

Statistical Analyses

Data were analyzed using the SPSS (version 26.0) statistical software package. Normality of distribution for outcome measures was tested using the Shapiro-Wilk test and it was determined that the data showed normal distribution. Descriptive statistics of the variables used in the analysis of data were shown as mean and standard deviation. Paired sample t-test was used to check possible differences between intervention. Statistical significance level was accepted as $p<0.05$.

RESULTS

In this part of the research, findings and comments regarding the data obtained as a result of statistical analyzes are given.

Table 1. Descriptive statistics of female roller skiers

n=9	Mean ± SD.	Range
Age	17.44 ± 1.13	16-19
Height	164.22 ± 3.73	160-169
BW	55.33 ± 6.46	46-65
BMI	20.47 ± 1.89	17.53-23.03
VO_{2max}	47.98 ± 1.14	44.53 – 54.00
Years of training	6.33 ± 1.32	4-8

Table 1 shows the age, height, BW, VO_{2max} and years of training mean values of the female roller skiers.

Table 2. Comparison of time trial performance average time between CAF and PLA trials

Distance	CAF (sec) Mean±SD.	PLA (sec) Mean±SD.	p
1000 m	190.33 ± 16.25	194.22±18.19	.724
2000 m	380.89 ± 27.62	377.78 ±28.71	.833
3000 m	574.22± 37.32	584.44 ± 56.53	.681
4000 m	770.56 ±44.45	788.44 ± 79.32	.598
5000 m	970 ± 56.98	991.78 ±87.19	.543
6000 m	1165.44±54.95	1190.22±105.95	.535
7000 m	1344.89± 57.22	1381.11±129.71	.422
8000 m	1531.44 ±88.83	1576.67 ± 142.31	.403

Table 2 shows the average time of the athletes according to distance until the end of the trial. The result of paired sample t-test showed there was no statistically significant difference between the CAF and PLA trials ($p>.05$). However, the examination of the average time for completing 8000-m roller skiing performance revealed that CAF reduced the time to complete the 8000-m time trial performance (CAF:1531.4 sec vs PLA:1576.6 sec).

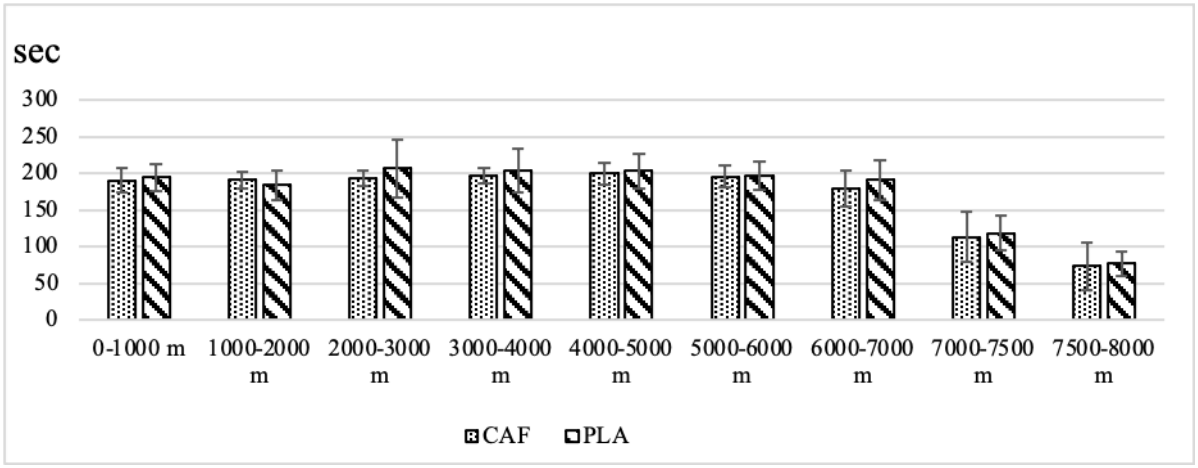

Figure 2. Effect of CAF and PLA on time trial performance by split times

Figure 2. shows the average time performed by the roller skiers to complete each split times. According to the analysis result there was no statistically significant difference between condition ($p>.05$). According to the figure, the average time for completing each 1000 meters was shorter under CAF conditions except for the 1000-2000-m distance.

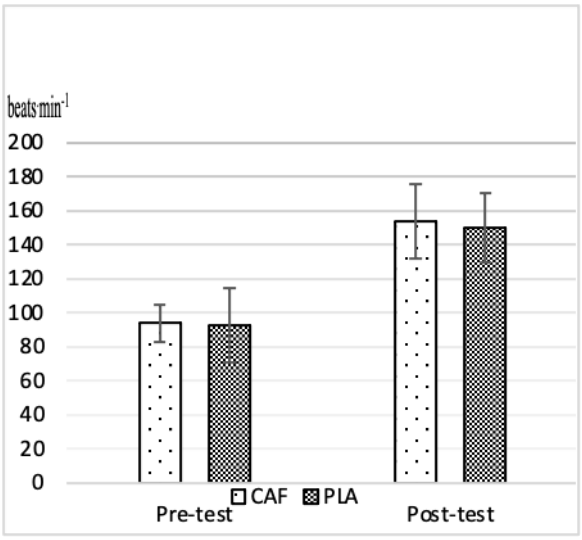

Figure 3. Comparison of pre and post test HR values between the CAF and PLA trials

Figure shows pre and post-test mean HR values of the female roller skiers and paired sample t-test result. The result of analysis showed there was no statistically significant difference pre-test as well as post-training HR values between CAF and PLA trials.

DISCUSSION and CONCLUSION

The aim of this study was to investigate the effect of relatively small dose of caffeine (3 mg.kg-1) ingestion on time trial 8000-m roller skiing performance and HR.

The major finding of this study was that the ingestion of a relatively small dose of caffeine (~3 mg.kg-1) 1h before an 8000-m time trial roller skiing resulted in a not statistically significant difference compared to PLA trial in performance time and HR. Although there was no statistically significant difference between the trials, the roller skiers completed 8000-m time trial performance faster in CAF trials. Caffeine ingestion resulted in an average

improvement of 45,23 seconds which is translated to a 2,93% improvement in performance time. Additionally, 66,6% of the participants completed 8000-m roller skiing time trial performance faster during the CAF trials compared to PLA trials.

In our study, time-trial performance improvement after CAF ingestion is in line with most of studies in the literature. Similarly, to our result, Bridge and Jones, (2006), in their study, found that the ingestion of relatively small dose of caffeine (3mg·kg^{-1} body mass) 1 h before an 8 km race resulted in a noticeable performance improvement in trained male distance runners. Stadheim et al., (2013), showed in their study with cross-country skaters that CAF ingestion (6 mg·kg^{-1}) reduced the time to complete the 8-km cross-country double poling performance. Bruce et al., (2000) investigated the effects of ingesting a 6 and 9 mg·kg^{-1} dose of caffeine or a placebo on the performance of eight well-trained male rowers in a 2000-m time trial. They reported a 1% improvement in performance time with both of caffeine doses. Anderson et al., (2000) in their study found a 0.7% reduction in time to complete a 2000-m time trial with a moderate dose of caffeine mg·kg^{-1} compared with placebo. On the contrary, a study conducted by Skinner et al., (2010), reported that the different doses of caffeine ingestion 1 h before exercise (2, 4 and 6 mg·kg^{-1}) had no effect on the 2000-m time trial rowing performance. In another study, the ingestion of 4 mg·kg^{-1} caffeine did not improve 10-km hand cycling time trial performance (Graham-Paulson et al., 2016). A meta-analysis study examining the effects of caffeine on time-trial performance showed that the caffeine provided a 4.4% ±3.1% improvement in time-trial performance compared to placebo (Glaister & Moir, 2019).

In the current study, althouhgh caffeine ingestion 1 hour before exercise did not provide statistically significant difference in time trial performance, it reduced the time to complete 8000-m roller ski performance. In such a sport, minutes or sometimes even seconds determine the winner of the competition. In this context consuming relatively small dose of caffeine (3 mg·kg^{-1}) 1h before 8000-m cross skating time trial performance can have positive effects on time trial performance.

During the CAF trial pre and post mean HR was higher compared to PLA trial, although it did not reach statistical significance. In the literature relative to placebo, some of the studies showed that caffeine supplementation resulted in a significant HR increase and some of them did not show any significant increase compared to placebo. Different results between the studies can be due to exercise protocol used, dose of caffeine ingested by athletes or training status of athletes. McNaughton et al., (2008) in their study showed CAF ingestion (6 mg.kg-1), resulted in no significant increase in HR relative to placebo in cycling performance lasting 60 minute. Similarly, in another study CAF ingestion (5 mg·kg^{-1}drink*) did not show any difference in HR compared to PLA in 45-min time trial cycling performance (Hodgson et al., 2013). Bortolotti et al. (2014) found as well that CAF ingestion (6 mg.kg-1) did not show any significant difference in HR relative to PLA in 20-km time trial cycling performance. On the other hand, there are studies in the literature which showed that CAF ingestion resulted in significant difference in HR compared to PLA. Laurence et al., (2012) in their study about CAF ingestion (6 mg·kg^{-1}) showed a statistically significant increase in HR compared to PLA in ~30 min time trial cycling performance. Even if HR was higher in CAF trials, it did not affect RPE. Bridge and Jones (2006) investigated the effect of CAF ingestion (3 mg·kg^{-1}) on

HR in runners and the result showed a statistically significant increase in HR relative to PLA in 8-km time trial running performance but the increase in HR did not increase RPE (Bridge & Jones, 2006).

In conclusion, ingestion of ~3 $mg \cdot kg^{-1}$ caffeine 1 h before exercise improved time trial performance in 8000-m roller skiers even it was not significantly different than PLA trial. Also, pre and post HR values were higher in CAF trial but did not reach statistically significance. Therefore, CAF gel might be used effectively pre-workout when supplementation during the exercise is not possible.

Conflict of interest

The authors declare that there is no conflict of interests.

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