European Journal of Sport Science

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tejs20

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Publisher: Taylor & Francis & European College of Sport Science

Journal: *European Journal of Sport Science*

DOI: 10.1080/17461391.2020.1857441

THE WEEK AFTER RUNNING A MARATHON: EFFECTS OF RUNNING vs ELLIPTICAL TRAINING vs RESTING ON NEUROMUSCULAR PERFORMANCE AND MUSCLE DAMAGE RECOVERY

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Abstract

Our aim was to compare the effects of two exercise modalities vs resting on the time course of neuromuscular performance and muscle damage recovery during the week after running a marathon. Sixty-four finishers from a road marathon completed the study (54 men and 10 women; 39 ± 4 years; 3 h 35 min ± 21 min). The day before the race, within 15 min after finishing the marathon and at 24, 48, 96, 144 and 192 h postrace, lactate dehydrogenase and creatine kinase were analyzed. Participants also performed a squat jump (SJ) test before and after the marathon and at 48, 96 and 144 h postrace. On their arrival to the finish line, participants were randomized into one of the three intervention groups: running (RUN), elliptical training (ELIP) and resting recovery (REST). RUN and ELIP groups exercised continuously for 40 min at a moderate intensity (95-105% of the HR corresponding to the first ventilatory threshold) at 48, 96 and 144 h after the marathon. Neither 'Intervention' factor nor 'Intervention x Time' interaction effects were revealed for muscle damage blood markers ($p>0.05$). On the other hand, RUN group evidenced an enhancement in SJ performance 96 h post-marathon as compared with REST group (108.29 ± 10.64 vs 100.58 ± 9.16%, $p=0.020$, $d=0.80$). Consequently, return to running at 48 h post-marathon does not seem to have a negative impact on muscle damage recovery up to eight days post-race and it could be recommended in order to speed up neuromuscular recovery.

Keywords: Fatigue, musculoskeletal, performance

1. Introduction

Road marathons have become one of the most popular vigorous exercise competitions nowadays as shown by the increasing number of amateur participants with hundreds of marathons worldwide (Ahmadyar, Rust, Rosemann, & Knechtle, 2015; Aschmann, Knechtle, Onywera, & Nikolaidis, 2018). Regardless of athlete's performance level, running a marathon places a high strain on body homeostasis over the course of several hours to days following the race (Bernat-Adell et al., 2019; Lijnen et al., 1988; Mansour et al., 2017; Panizo Gonzalez et al., 2019; Roca et al., 2017; Scherr et al., 2011). Particularly, exercise-induced muscle damage (EIMD) symptoms, such as soreness, swelling, reduced range of motion (ROM) and reduced neuromuscular function often constitute a limiting factor in athletes' return to regular training. Thus, for both recreational and highly-trained runners, optimizing post-marathon recovery is crucial. However, research regarding return to training following the marathon is scarce and there is not a clear consensus whether rest or exercise facilitate recovery of muscle damage and function.

In the classic study by Sherman et al. (1984), a group of 10 marathoners were subjected to either rest or running exercise of gradually increasing duration (from 20 to 45 min) and self-selected intensity during the 6 days following the race. Resting recovery group evidenced a slightly better muscle function recovery than running group and the authors concluded that if active recovery was selected the week post-marathon, both intensity and duration must be judiciously programmed. However, running performed the week post-marathon has been suggested to likely increase the time before muscle regeneration sets in as a result of eccentric contractions which occur when running (Wiewelhove et al., 2016). Hence, it seems reasonable to opt for exercise modalities in which the body weight is borne by an external element and the eccentric strain is consequently reduced (i.e., cycling, swimming, elliptical machine, etc.) (Wiewelhove et al., 2018).

Given this scenario, further studies where different exercise modalities (i.e., those in which body weight is borne by an external element vs. those in which body weight is not borne by an external element) performed at the same relative intensity and for the same duration are warranted to establish the preferable recovery strategy to enhance neuromuscular performance and muscle damage recovery during the week post-marathon. Therefore, the aim of the study was to analyze the effects of two exercise modalities (running vs elliptical training) vs resting on the time course of neuromuscular performance and muscle damage recovery during the week after running a marathon. We hypothesized that muscle damage recovery would be faster in resting and elliptical training groups compared to the running group (Sherman et al., 1984; Wiewelhove et al., 2016), whereas neuromuscular performance recovery would be faster in the elliptical training group (Nakagawa et al., 2018).

2. Material and methods

Participants

All participants in the Valencia Trinidad Alfonso EDP 2016 Marathon received an invitation email to participate in the study. Two information seminars were organized in order to fully explain the study design (aims, measurements, etc.) to those individuals who accepted the invitation (N = 456). A total of 98 runners (83 males and 15 females) were selected to participate in this study, according to the following inclusion criteria: age between 30 and 45 years; body mass index (BMI) between 16 and 24.99 $kg \cdot m^{-2}$; previous marathon experience; having a performance best time in marathon between 3 and 4 hours for males and 3:30 and 4:30 hours for females; and healthy individuals who were free from cardiac or renal disease and from taking any medication on a regular basis. All individuals included in the current study were fully informed and gave their written consent to participate. The research was conducted according to the Declaration of Helsinki, and it was approved by the Research Ethics Committee of the Jaume I University of Castellon. This study is enrolled in the ClinicalTrails.gov database, with the code number NCT03155633 (www.clinicaltrials.gov).

From the initial sample of 98 participants, 88 runners finished the marathon and 64 athletes completed post-race intervention and constitute the final sample of the study (**Table 1**): 24 participants in REST group (20 men and 4 women), 21 participants in RUN group (18 men and 3 women) and 19 participants in ELIP group (16 men and 3 women). Drop out was due to failure in attending training or testing sessions. Average finishing time for REST, RUN and ELIP groups were 3h:34min:15s ± 21min:23s, 3h:33min:51s ± 22min:21s and 3h:36min:42s ± 18min:47s respectively.

Cardiopulmonary exercise test

Cardiopulmonary exercise tests (CPET) were performed on a treadmill (H/P/cosmos pulsar, H/P/cosmos sports & medical GmbH, Nussdorf-Traunstein, Germany) between 2 to 4 weeks prior to the marathon. Pulmonary VO_2 and VCO_2 were measured breath-by-breath using an automated online system (Oxycon Pro system, Jaeger, Würzburg, Germany). Gas analysis system was calibrated for ambient temperature and humidity, air flow and VO_2 and VCO_2 concentrations (with a 4.96% CO_2 – 12.10% O_2 gas mixture) before each testing session according to manufacturer instructions (Rietjens et al. 2001). CPET protocol consisted of 3 min warm up at 6 km·h^{-1} and 1% slope followed by ramp speed increases of 0.25 km·h^{-1} every 15s until volitional exhaustion. A 3-min constant speed stage at 11 km·h^{-1} for women and 12 km·h^{-1} for men was included in the protocol so as to enable running economy measurements. Maximum oxygen uptake (VO_2max) values were accepted when a plateau (an increase of <2ml/kg/min) or a decline in VO_2 was reached despite increasing workloads and a respiratory exchange ratio (RER) above 1.15 was achieved. If this criteria was not met, a VO_2peak value was taken, defined as the highest VO_2 measured over a 30 seconds period. First and second ventilatory thresholds (VT_1 and VT_2) were determined using Skinner and McLellan (1980) guidelines by two independent researchers.

Neuromuscular assessment

Squat jump (SJ) test was employed to assess neuromuscular performance before the race, after finishing the marathon and at 48, 96 and 144 h postrace. Participants were asked to jump as high as possible from a starting position with hips and knees flexed 80 degrees and hands stabilized on hips to avoid arm-swing. Jump height was estimated by the flight time measured with a contact platform (Chronojump, Barcelona, Spain). Subjects were familiarized with the procedure before testing was conducted.

Blood sampling and analysis

Blood samples were collected from an antecubital vein by venipuncture the day before the race, within 15 min after finishing the marathon and at 24, 48, 96, 144 and 192 h postrace using BD Vacutainer PST II tubes. Samples were centrifuged at 3500 rpm for ten minutes and kept at 4°C during transport to Vithas-Nisa 9 de Octubre Hospital (Valencia), where they were processed using the modular platform Roche / Hitachi clinical chemistry analyzer Cobas c311 (Roche Diagnostics, Penzberg, Germany), as previously published (Bernat-Adell et al., 2019). Lactate dehydrogenase (LDH) and creatine kinase (CK) were used as muscle damage blood markers.

Post-marathon intervention

Participants were randomized just after arriving to the finish line into one of the three intervention groups: running (RUN), elliptical training (ELIP) and resting recovery (REST). Regardless of the assigned group, participants did not train for the first 48 h following the race. From this point onwards, RUN and ELIP groups train at 48 h, 96 h and 144 h after the marathon, whereas REST group remain without training until 192 h following the race. RUN and ELIP participants exercised continuously for 40 min at a moderate intensity (between 95-105% of the heart rate corresponding to the VT_1) each of these three days. They were all equipped with a Polar M400 HR monitor (Kempele, Finland) and training sessions were supervised by a member of the research team who verified that targeted intensity was met. RUN participants trained on an outdoor track while ELIP participants exercised at one of two indoor gym facilities using the same equipment (Synchro excite 500, Technogym, Cesena, Italia). Blood drawings and SJ testing in the RUN and ELIP participants were performed immediately before the training session.

Statistical analyses

Statistical analyses were carried out using the Statistical Package for the Social Sciences software (IBM SPSS Statistics for Windows, version 22.0, IBM Corp., Armonk, NY). For the purpose of the current paper, we only considered SJ results of 48, 96 and 144 h postrace and CK and LDH values of 48, 96, 144 and 192 h postrace. A two-factor repeated-measures ANOVA was conducted, with 'Intervention' (RUN vs ELIP vs REST) as between-factor and 'Time' (48, 96, 144 and 192 h post-race) as within-factor, to assess the effect of post-marathon training on muscle damage recovery. The same procedure was employed to appraise possible differences in neuromuscular performance between the abovementioned intervention groups. Whenever Mauchly's Sphericity test was violated, necessary technical corrections were performed using the Greenhouse-Geisser test; and for each ANOVA, if a significant main effect or interaction was identified, Bonferroni post-hoc comparisons were conducted. SJ, CK and LDH values at 48 h postrace were set as an individual 100% for each participant and subsequent values were normalized to this baseline level before performing the ANOVAs. On the other hand, the meaningfulness of the outcomes was estimated through the partial estimated effect size (η2 partial) for ANOVA and Cohen's d effect size for pairwise comparisons. In the latter case, a Cohen's D<0.5 was considered small; between 0.5-0.8, moderate; and greater than 0.8, large (Thomas, Nelson, & Silverman, 2005). The significance level was set at p-value <0.05 and data are presented as means and standard deviations (±SD).

3. Results

Values of CK, LDH and SJ are presented in **Table 2**. Univariate contrast analysis showed a significant effect for 'Time' on CK [F=437.621; p<0.01; η2 partial=0.88], LDH [F=133.250; p<0.01; η2 partial=0.69] and SJ [F=5.625; p=0.005; η2 partial=0.08]. Neither 'Intervention' factor nor 'Intervention x Time' interaction effects were revealed for muscle damage blood markers (see **Figure 1A and 1B**).

Conversely, SJ was significantly affected by both 'Intervention' factor [F=3.364; p=0.041; η2 partial=0.10] and 'Intervention x Time' interaction [F=2.575; p=0.041; η2 partial=0.08]. Bonferroni adjusted pairwise comparisons showed that RUN group significantly improved from 48h post-race to 96h post-race, whereas SJ height remained unchanged in REST and ELIP groups (see **Figure 2**). Moreover, at 96h post-race SJ height was significantly and moderately better in RUN compared to REST group (108.29 ± 10.64% vs 100.58 ± 9.16%, p=0.020, *d*=0.80) and the difference between RUN and ELIP group approached statistical significance (108.29 ± 10.64% vs 101.89 ± 7.10%, p=0.093, *d*=0.72).

4. Discussion

The present study examined the effect of performing an active recovery (running or elliptical training) or a passive recovery the week post-marathon upon muscle damage recovery and neuromuscular performance. Our results demonstrate that muscle damage recovery is neither accelerated nor decelerated by exercising on alternate days from 48 h post-marathon onwards at a moderate intensity. Moreover, no difference was identified between running and elliptical training regarding muscle damage recovery. Our first hypothesis that muscle damage recovery would be faster in resting and elliptical training groups compared to the running group was thus not corroborated by the results.

SJ height of the male participants corresponded to the 75 to 90th percentile of previously reported among recreational marathoners (Nikolaidis, Del Coso, Rosemann, & Knechtle, 2019), while SJ performance of the female participants was better than previously reported mean values in this population (Nikolaidis, Rosemann, & Knechtle, 2018). Our results showed that those athletes who performed a running training at 48 h post-marathon evidenced an enhancement in their neuromuscular performance at 96 h post-marathon, unlike participants who did elliptical training or passive recovery and whose SJ height remained unchanged. Accordingly, our second hypothesis that neuromuscular performance recovery would be faster in the elliptical training group was neither corroborated by the results. Notwithstanding, the absence of changes in SJ height among runners who did passive recovery is in line with a previous study in the field (Petersen, Hansen, Aagaard, & Madsen, 2007), where authors showed that countermovement jump power remained significantly suppressed compared to pre-marathon values five days following the race in a group of highly-trained athletes. In addition, the fact that RUN group enhanced their neuromuscular performance at 96 h post-marathon compared to REST group matches in some way the findings of a prior investigation which analyzed the effect of wearing unstable rocker shoes (Masai Barefoot Technology shoes: MBT shoes) during the week after running a marathon (Nakagawa et al., 2018). In this study authors demonstrated a faster recovery of isometric torque in knee flexion and muscle hardness in the gastrocnemius and vastus lateralis (i.e., neuromuscular performance) in the experimental group.

In light of the abovementioned results, running at a moderate intensity (between 95 and 105% of the HR corresponding to VT_1) for 40 min two days after completing a marathon does not seem to have a negative impact on muscle damage recovery, which is a prime purpose following a long distance race (Hoffman, Badowski, Chin, Stuempfle, & Parise, 2017). Furthermore, it appears to have a positive effect on neuromuscular performance. Therefore, return to running could be addressed 48 h post-marathon, although faster runners are advised to delay such return to running (approximately until 96 h following the race) as a slower muscle damage recovery pattern has been described among better-performing athletes (Bernat-Adell et al., 2019). Similarly, a recent study which focused on possible changes in running gait pattern following a marathon found an elevated peak mediolateral acceleration associated with atypical running biomechanics 2 days after the race and suggested that this alteration was linked to an increased injury risk (Clermont, Pohl, & Ferber, 2019). Hence, although our results showed that no detrimental effects on muscle damage recovery are involved in return to running 48 h post-marathon, both coaches and athletes are suggested to avoid it in the event of elevated musculoskeletal pain, reduced ROM or joint compliance that could affect running biomechanics. In the meantime, considering that increased muscle tightness in ankle, knee and hip joints have been described until five days post-marathon in recreational runners (Tojima, Noma, & Torii, 2016), elliptical training rather than running may be the preferable approach during the week post-marathon in athletes who experience any of the abovementioned EIMD symptoms (Cheung, Hume, & Maxwell, 2003).

There are some limitations in our study that should be acknowledged. Regarding the recovery assessment, the addition of muscle soreness, ROM and/or muscle tightness measurements would have allowed us to reach a broader view of the effects of active vs passive recovery during the week post-marathon. In terms of post-marathon intervention, it could be argued that a combination of resting and training (i.e., resting until 96 h post-race and running at 96 h and 144 h post-race) may provide the best return-to-training approach during the week post-marathon. Nevertheless, our study has the strength of having been conducted on a sample of 64 athletes whose post-race training was tailored (i.e., intensity was adjusted using HR values derived from CPET) and supervised during the whole week post-marathon. Moreover, we performed serial blood drawings (pre-race, immediately postrace and at 24, 48, 96, 144 and 192 h postrace) together with neuromuscular assessments at 48, 96 and 144 h postrace.

5. Conclusions

No differences were found between running, elliptical training and resting groups in muscle damage recovery from 48 h to 192 h post-marathon. In addition, those athletes who performed a running training at a moderate intensity 48 h post-marathon evidenced an enhancement in SJ performance 96 h post-marathon. Consequently, return to running at 48 h post-marathon does not seem to have a negative impact on muscle damage recovery up to eight days post-race and it could be recommended in order to speed up neuromuscular recovery. However, in the event that the athlete report elevated musculoskeletal pain and/or increased muscle tightness that could affect running biomechanics, elliptical training would be more suitable than running. It is hoped that the findings from this study will help inform practice of athletes and coaches in relation to the suitability of the different training vs resting approaches during the week post-marathon.

Acknowledgements

Current research could be carried out thanks to the collaboration of Fundacion Trinidad Alfonso, Vithas-Nisa Hospitals group and Sociedad Deportiva Correcaminos. Authors are also grateful to all the staff involved in the organization of the Valencia Fundacion Trinidad Alfonso EDP 2016 Marathon and all marathoners and volunteers participating in this study. The funders had no involvement in the study design, data collection, analysis and interpretation, writing of the manuscript and decision to submit the paper for publication.

References

Ahmadyar, B., Rust, C. A., Rosemann, T., & Knechtle, B. (2015). Participation and performance trends in elderly marathoners in four of the world's largest marathons during 2004-2011. *Springerplus, 4*, 465. doi: 10.1186/s40064-015-1254-6

Aschmann, A., Knechtle, B., Onywera, V., & Nikolaidis, P. T. (2018). Pacing strategies in the New York City Marathon-Does nationality of finishers matter? *Asian Journal of Sports Medicine, 9*(2), e57596

Bernat-Adell, M. D., Collado-Boira, E. J., Moles-Julio, P., Panizo-Gonzalez, N., Martinez-Navarro, I., Hernando-Fuster, B., & Hernando-Domingo, C. (2019). Recovery of

Inflammation, Cardiac, and Muscle Damage Biomarkers After Running a Marathon. *J Strength Cond Res*. doi: 10.1519/JSC.0000000000003167

Clermont, C. A., Pohl, A. J., & Ferber, R. (2019). Fatigue-Related Changes in Running Gait Patterns Persist in the Days Following a Marathon Race. *J Sport Rehabil*, 1-8. doi: 10.1123/jsr.2019-0206

Cheung, K., Hume, P., & Maxwell, L. (2003). Delayed onset muscle soreness : treatment strategies and performance factors. *Sports Med, 33*(2), 145-164. doi: 10.2165/00007256-200333020-00005

Hoffman, M. D., Badowski, N., Chin, J., Stuempfle, K. J., & Parise, C. A. (2017). Determinants of recovery from a 161-km ultramarathon. *J Sports Sci, 35*(7), 669-677. doi: 10.1080/02640414.2016.1183808

Lijnen, P., Hespel, P., Fagard, R., Lysens, R., Vanden Eynde, E., Goris, M., Goossens, W., Lissens, W., & Amery, A. (1988). Indicators of cell breakdown in plasma of men during and after a marathon race. *Int J Sports Med, 9*(2), 108-113. doi: 10.1055/s-2007-1024989

Mansour, S. G., Verma, G., Pata, R. W., Martin, T. G., Perazella, M. A., & Parikh, C. R. (2017). Kidney Injury and Repair Biomarkers in Marathon Runners. *Am J Kidney Dis, 70*(2), 252-261. doi: 10.1053/j.ajkd.2017.01.045

Nakagawa, K., Inami, T., Yonezu, T., Kenmotsu, Y., Narita, T., Kawakami, Y., & Kanosue, K. (2018). Unstable rocker shoes promote recovery from marathon-induced muscle damage in novice runners. *Scand J Med Sci Sports, 28*(2), 621-629. doi: 10.1111/sms.12911

Nikolaidis, P. T., Del Coso, J., Rosemann, T., & Knechtle, B. (2019). Muscle Strength and Flexibility in Male Marathon Runners: The Role of Age, Running Speed and Anthropometry. Front Physiol, 10, 1301. doi: 10.3389/fphys.2019.01301

Nikolaidis, P. T., Rosemann, T., & Knechtle, B. (2018). Force-Velocity Characteristics, Muscle Strength, and Flexibility in Female Recreational Marathon Runners. Front Physiol, 9, 1563. doi: 10.3389/fphys.2018.01563

Panizo Gonzalez, N., Reque Santivanez, J. E., Hernando Fuster, B., Collado Boira, E. J., Martinez-Navarro, I., Chiva Bartoll, O., & Hernando Domingo, C. (2019). Quick Recovery of Renal Alterations and Inflammatory Activation after a Marathon. *Kidney Dis (Basel), 5*(4), 259-265. doi: 10.1159/000500510

Petersen, K., Hansen, C. B., Aagaard, P., & Madsen, K. (2007). Muscle mechanical characteristics in fatigue and recovery from a marathon race in highly trained runners. *Eur J Appl Physiol, 101*(3), 385-396. doi: 10.1007/s00421-007-0504-x

Roca, E., Nescolarde, L., Lupon, J., Barallat, J., Januzzi, J. L., Liu, P., Cruz Pastor, M., & Bayes-Genis, A. (2017). The Dynamics of Cardiovascular Biomarkers in non-Elite Marathon Runners. *J Cardiovasc Transl Res, 10*(2), 206-208. doi: 10.1007/s12265-017-9744-2

Scherr, J., Braun, S., Schuster, T., Hartmann, C., Moehlenkamp, S., Wolfarth, B., Pressler, A., & Halle, M. (2011). 72-h kinetics of high-sensitive troponin T and inflammatory markers after marathon. *Med Sci Sports Exerc, 43*(10), 1819-1827. doi: 10.1249/MSS.0b013e31821b12eb

Sherman, W. M., Armstrong, L. E., Murray, T. M., Hagerman, F. C., Costill, D. L., Staron, R. C., & Ivy, J. L. (1984). Effect of a 42.2-km footrace and subsequent rest or exercise on muscular strength and work capacity. *J Appl Physiol Respir Environ Exerc Physiol, 57*(6), 1668-1673. doi: 10.1152/jappl.1984.57.6.1668

Skinner, J. S., & McLellan, T. M. (1980). The transition from aerobic to anaerobic metabolism. *Res Q Exerc Sport, 51*(1), 234-248. doi: 10.1080/02701367.1980.10609285

Thomas, J., Nelson, J., & Silverman, S. (2005). *Research Methods in Physical Activity*. Champaign: Human Kinetics.

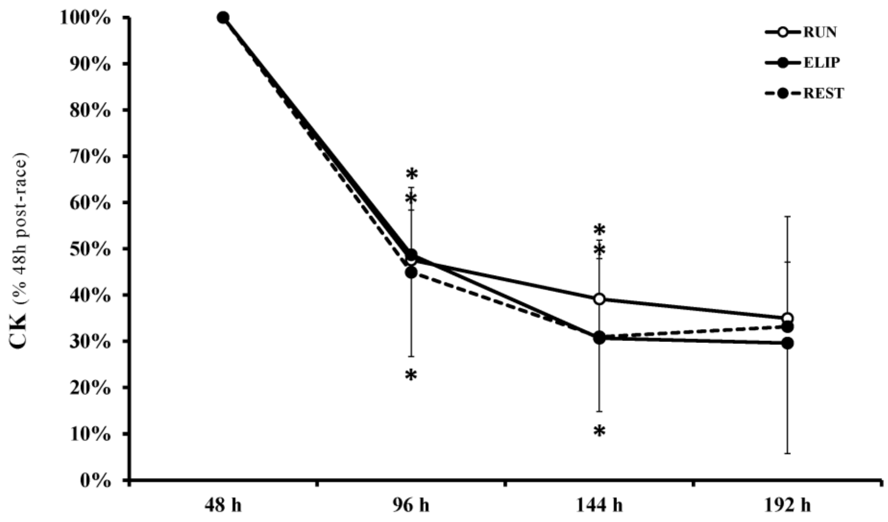
Tojima, M., Noma, K., & Torii, S. (2016). Changes in serum creatine kinase, leg muscle tightness, and delayed onset muscle soreness after a full marathon race. *J Sports Med Phys Fitness, 56*(6), 782-788

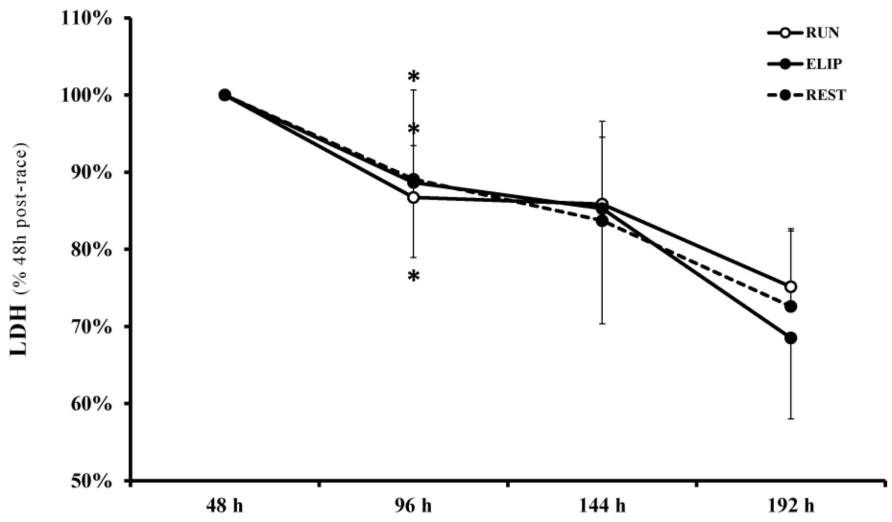
Wiewelhove, T., Raeder, C., Meyer, T., Kellmann, M., Pfeiffer, M., & Ferrauti, A. (2016). Effect of Repeated Active Recovery During a High-Intensity Interval-Training Shock

Microcycle on Markers of Fatigue. *Int J Sports Physiol Perform, 11*(8), 1060-1066. doi: 10.1123/ijspp.2015-0494

Wiewelhove, T., Schneider, C., Doweling, A., Hanakam, F., Rasche, C., Meyer, T., Kellmann, M., Pfeiffer, M., & Ferrauti, A. (2018). Effects of different recovery strategies following a half-marathon on fatigue markers in recreational runners. *PLoS One, 13*(11), e0207313. doi: 10.1371/journal.pone.0207313

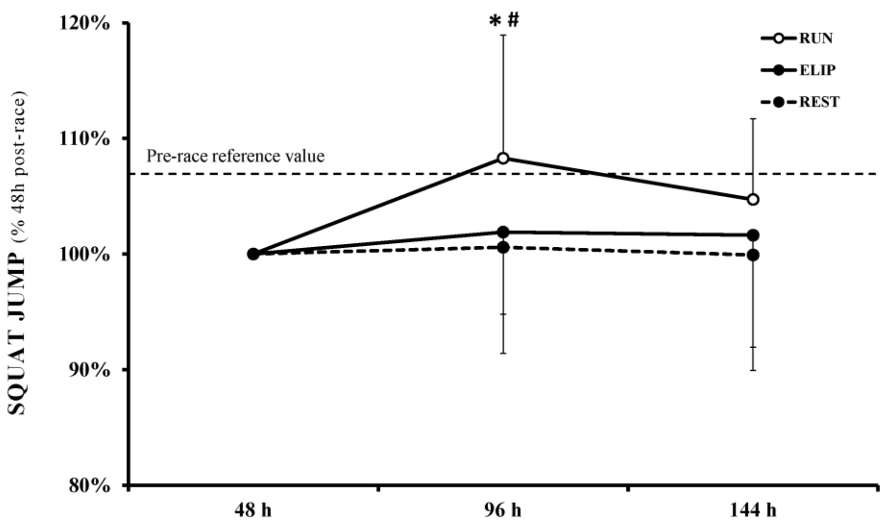
Figure 1. CK (panel A) and LDH (panel B) evolution following the marathon





* Significantly different from previous blood drawing

Figure 2. SJ height evolution following the marathon



* Significantly different from previous measurement; # Significantly different from REST group

Table 1. Sample main characteristics (mean ± SD)

	All sample (n = 64)	Males (n = 54)	Females (n = 10)
Age (years)	39 ± 4	39 ± 4	39 ± 2
BMI (kg/m^2)	22.9 ± 1.7	23.2 ± 1.5	21.2 ± 1.5
SJ (cm)	26.9 ± 4.4	27.9 ± 4.1	21.8 ± 2.2
VO_{2peak} (ml O_2/kg/min)	54.1 ± 5.5	55.2 ± 5.2	48.1 ± 3
V_{peak} (km/h)	17 ± 1.2	17.3 ± 1	15.3 ± 0.5
V_{VT1} (km/h)	11.5 ± 0.9	11.7 ± 0.8	10.3 ± 0.6
V_{VT2} (km/h)	14 ± 0.9	14.2 ± 0.9	13.1 ± 0.7
Number of years running	7 ± 3	7 ± 3	6 ± 3
Number of previous marathons	4 ± 3	4 ± 3	2 ± 3
Weekly training days	5 ± 1	5 ± 1	5 ± 1
Weekly running volume (km)	63 ± 13	64 ± 14	59 ± 10
Weekly training hours	7 ± 2	7 ± 3	7 ± 2
Strength training (yes/no)	37% / 61%	37% / 61%	40% / 60%

Abbreviations: BMI, Body Mass Index; SJ, squat jump; VO_2peak, peak oxygen uptake; V_{peak}, peak speed reached at the Cardiopulmonar Exercise Test; V_{VT1}, speed associated with the first ventilatory threshold in the Cardiopulmonar Exercise Test; V_{VT2}, speed associated with the second ventilatory threshold in the Cardiopulmonar Exercise Test; Strength training (%), percentage of participants who performed at least one weekly strength-training in the previous 3 months.

Table 2. Muscle damage biomarkers and SJ height absolute values (mean ± SD)

	REST (n = 24)	**RUN** (n = 21)	**ELIP** (n = 19)
48h post-race CK (Ul/L)	715.25 ± 744.44	777.9 ± 1195.1	1303.68 ± 1614.2
96h post-race CK (Ul/L)	295.79 ± 424.33	316.1 ± 368.54	750.79 ± 1285.87
144h post-race CK (Ul/L)	136.54 ± 65.36	245.86 ± 262.39	378.79 ± 502.26
192h post-race CK (Ul/L)	133.54 ± 60.7	198.24 ± 161.6	215.21 ± 152.02
48h post-race LDH (Ul/L)	253.79 ± 48.97	261.29 ± 64.05	271.42 ± 53.48

96h post-race LDH (Ul/L)	223.75 ± 39.2	224.57 ± 46.17	244.11 ± 48.99
144h post-race LDH (Ul/L)	210.04 ± 35.61	220.19 ± 38.51	228.11 ± 44.12
192h post-race LDH (Ul/L)	181.33 ± 25.13	194.38 ± 39.36	182.58 ± 26
48h post-race SJ (cm)	25.3 ± 4.8	24.68 ± 4.1	25.55 ± 4.34
96h post-race SJ (cm)	25.27 ± 4.21	26.5 ± 3.6	26.08 ± 4.85
144h post-race SJ (cm)	25 ± 3.85	25.73 ± 3.86	25.95 ± 4.87

Abbreviations: CK, Creatine kinase; LDH, Lactate dehydrogenase; SJ, Squat Jump