

1 SHORT TERM CREATINE LOADING WITHOUT WEIGHT GAIN IMPROVES SPRINT,
2 AGILITY AND LEG STRENGTH PERFORMANCE IN FEMALE FUTSAL PLAYERS

3 **Summary**

4 **Objectives.** Futsal game requires players to perform frequent bouts of high-intensity activity
5 with limited rest periods that are not sufficient for full recovery. Therefore, creatine
6 supplementation may enhance performance by improving recovery rate. Along with this, the
7 number of studies conducted to determine the effects of creatine on performance in the
8 females is scarce. Thus, the main aim of this study is to identify the effects of short-term
9 (7/day) creatine supplementation on leg strength, velocity and agility in young female futsal
10 players.

11

12 **Equipment and methods.** A total of thirty of young female futsal players (aged: 19.83 ± 1.13
13 years) participated in the study which was designed as randomized and double-blind, on a
14 voluntary basis. Participants were randomly assigned either to Creatine (n=15) or Placebo
15 (n=15) group. Over 7 days, Creatine group received 0.25 g/kg/day micronized pure creatine
16 monohydrate (Creapure, Hardline Nutrition, Kavi Gıda Istanbul, Turkey) and placebo group
17 did not take any supplements, apart from maltodextrin (Fantomalt, Nutricia, United
18 Kingdom). Before and after 7 days of loading creatine supplementation, body weight, leg
19 strength, velocity and agility performance of the participants were determined. The data
20 obtained were analysed with ANCOVA statistical model.

21

22 **Results.** Creatine supplementation significantly improved 10m, 20m and 30m speed
23 performances ($p < 0.05$), leg strength ($p < 0.05$) and agility ($p < 0.05$) in female futsal players.
24 Depending on the creatine loading, however, no significant change in body weight was
25 observed ($p > 0.05$). The data obtained provide that 7 days low dose creatine supplementation
26 may be an effective approach for improving exercise capacity in female futsal players
27 without an associated increase in body weight.

28 **Key words:** Creatine, ergogenic aid, futsal, female, performance

29

30

31 LA CHARGE DE CRÉATINE À COURT TERME SANS GAIN DE POIDS AMÉLIORE
32 LA PERFORMANCE DU SPRINT, DE L'AGILITÉ ET DE LA RÉSISTANCE AUX
33 JAMBES CHEZ LES JOEUSES FUTSAL FÉMININES

34 **Résumé**

35 **Objectifs:** Le jeu de futsal exige que les joueurs effectuent de fréquentes périodes d'activité
36 de haute intensité avec des périodes de repos limitées qui ne sont pas suffisantes pour une
37 récupération complète. Par conséquent, la supplémentation en créatine peut améliorer les
38 performances en améliorant le taux de récupération. Parallèlement à cela, le nombre d'études
39 menées pour déterminer les effets de la créatine sur la performance chez les femmes est rare.
40 Ainsi, le but principal de cette étude est d'identifier les effets de la supplémentation en
41 créatine à court terme (7/jour) sur puissance des jambes, la vitesse et l'agilité chez les jeunes
42 joueuses de futsal féminines.

43

44 **Équipement et méthodes:** Au total, une trentaine de jeunes joueuses de futsal (âgées de
45 $19,83 \pm 1,13$ ans) ont participé à l'étude, conçue comme une étude randomisée et en double
46 aveugle, sur base volontaire. Les participants ont été assignés au hasard soit au groupe
47 Créatine (n = 15) ou au groupe Placebo (n = 15). Sur 7 jours, le groupe Créatine a reçu 0,25 g
48 / kg / jour de monohydrate de créatine pure micronisée (Creapure, Hardline Nutrition, Kavi
49 Gıda Istanbul, Turquie) et le groupe Placebo n'a pas pris de suppléments hormis la
50 maltodextrine (Fantomalt, Nutricia, Royaume-Uni). Avant et après 7 jours de chargement de
51 supplémentation en créatine, le poids corporel, la force des jambes, la vitesse et l'agilité des
52 participants ont été déterminés. Les données obtenues ont été analysées avec le modèle
53 statistique ANCOVA.

54

55 **Résultats:** La supplémentation en créatine a significativement amélioré les performances en
56 vitesse de 10m, 20m et 30m ($p < 0.05$), la force des jambes ($p < 0.05$) et l'agilité ($p < 0.05$)
57 chez les joueuses de futsal. Cependant, en fonction de la charge en créatine, aucun
58 changement significatif du poids corporel n'a été observé ($p > 0,05$). Les données obtenues
59 indiquent qu'une supplémentation en créatine à faible dose de 7 jours peut être une approche
60 efficace pour améliorer la capacité d'exercice chez les joueuses féminines de futsal sans
61 augmentation associée du poids corporel.

62 **Mots-clés:** Créatine, aide ergogénique, futsal, féminines, performance

63 **1. Introduction**

64 In the last three decades, futsal game has reached an increasing popularity and also developed
65 so fast after its full accreditation by the Fédération Internationale de Football Association
66 (FIFA) in 1989. Similarly, studies conducted over futsal have been expanding and reached to
67 88 Pubmed publication in 2016 April from 52 in 2014 August (1). Futsal is an indoor model
68 of soccer with the high physical demands and consisting of 5 players in each team including a
69 goalkeeper. According to the futsal game motion-time analysis, it has been shown that futsal
70 has intermittent high-intensity movement features dominantly (2). Additionally, some
71 different features of futsal game, such as the smaller playing area, frequent and fast direction
72 changes, require quick decision making, which ensues repeated sprints and agility capacity as
73 crucial factor to improve in performance (1, 3, 4). On the other hand, from the biochemical
74 point of view, the creatine/phosphocreatine (PCr) system can supply phosphate to the cell to
75 compensate adenosine triphosphate (ATP) deficit during high-intensity workouts (5, 6). Due
76 to the aforementioned use of creatine phosphate during high-intensity exercises, Creatine
77 monohydrate (CrM) supplementation has become very popular particularly in soccer (7) and
78 some other team sports (8). Particularly, 7 days CrM loading has been shown to improve
79 sprint power, endurance, dribble and a vertical jump test (9) which have been using to
80 simulate the soccer game movements and exercises (7). Another short-term creatine (Cr)
81 loading study has been applied over 6 days and found improvements in agility and repeated
82 sprint performances in highly trained female soccer players (10). Along with this, some
83 studies found 7 days Cr supplementation with no effect on dribbling, agility (with and
84 without the ball) and sprint performance in male futsal players (11). To our knowledge, there
85 is only one study evaluating Cr loading on motor performance in female futsal players over
86 two weeks, where the positive effect of Cr supplementation wingate anaerobic power,
87 capacity, 20 m sprint and, muscular power performance were demonstrated (12). So the aim
88 of this study is to assess effects of a short-term (7 days), low dose Cr loading on sprint
89 performance, leg strength and agility in elite female futsal players. The experimental exercise
90 tests used in this study were selected based on similar activity patterns with futsal game.

91
92
93
94
95

96 **2. Materials and Methods**

97 **2.1 Participants**

98 This study was conducted in the Department of Physical Education and Sport at Dumlupinar
99 University in Kutahya, Turkey. Thirty highly trained Turkish female futsal players ($19.8 \pm$
100 1.14 years, 164.2 ± 6.47 cm, 56.2 ± 6.34 kg) from the same team voluntarily participated in
101 this study. A written consent was obtained from the subjects after they were thoroughly
102 informed of the purpose and potential risks of participating in the study. All experimental
103 tests and procedures were conducted according to the declaration of Helsinki and all
104 participants understood and signed an informed consent which was approved by the
105 university ethical board. All subjects were competing in the Turkish first division women
106 futsal league during the course of the study. They've had minimum continuous futsal training
107 background of $4.53 \pm .83$ yr of experience. None of the participating players was vegetarian or
108 ate unusually large quantities of meat. This study was performed in February, which was the
109 official league break period and no official game was played so. Only the subjects who had
110 never been supplemented with CrM/maltodextrin or had never used anabolic steroids, were
111 allowed to participate in this study to avoid unknown possible physiological adaptations.

112 **2.2. Experimental Design**

113 A double-blind, placebo-controlled, randomized design was used in this study. After the
114 baseline anthropometric measurements, the subjects were assigned to either a creatine group
115 (CrG n= 15) supplementation group or a placebo (PIG n= 15) group by using the online
116 research randomizer (<https://www.randomizer.org/>) website. All trials were performed
117 approximately at the same time of the day, between 14 pm to 16 pm. After that; 10m, 20m
118 and 30m sprints, agility and leg strength performance tests were applied, respectively. Five
119 minutes rest were given between each test. The same protocol was repeated after 7 days Cr
120 supplementation. Subjects were instructed to maintain their normal diet throughout the testing
121 period, to avoid food and drink in the hour before each trial. None of them declared using
122 dietary supplements for at least 2 months before the baseline. All of the subjects underwent
123 the same training schedules during the protocol and also they were familiarized with each
124 exercise testing protocol separately, moreover, during the previous season they had been
125 tested with the same testing procedures several times.

126

127 **2.2.1. Supplementation Protocol**

128 After pretreatment testing, subjects were divided into either CrG or PlG. None of the subjects
129 had ingested CrM, or any other dietary supplements before initiation of the study. CrG group
130 received 0.25 g/kg/day micronized pure CrM (Creapure, Hardline Nutrition, Kavi Gıda
131 Istanbul, Turkey) for 7 days. PlG group received 0.25 g/kg/ day maltodextrin (Fantomalt,
132 Nutricia, UK) for 7 days, which was matched with the Cr powder for taste and colour. The
133 supplement was equally divided into two for consuming in breakfast and dinner to avoid the
134 reduction in urinary creatinine excretion and increase in whole-body retention of Cr (13).
135 Subjects mixed their supplement with ~300 mL of a warm water before consuming. During
136 the course of the study, the subjects were asked to refrain from exhaustive physical activity,
137 caffeine and alcohol consumption for 24 hours prior to testing.

138 **2.2.2 Anthropometric Measurements**

139 Before and after the supplementation protocol was started applying, body height and body
140 weight of the participants was measured with a standard digital scale accurate to the nearest \pm
141 1 mm (Holtain Ltd. U.K.) and scale accurate to the nearest 0.1 kg (Tanita TBF 401 A Japan),
142 respectively. All pre and post measurements were conducted at the approximately same time
143 of the day.

144 **2.2.3. Leg Strength**

145 The isometric leg strength of 30 subjects was measured using Takei (Takei Kiki Kogyo,
146 Tokyo, Japan) portable, back and lift dynamometer and results were saved as kg. All subjects
147 stood upright on the base of the dynamometer with their feet shoulder-width apart. They were
148 asked to bend their back slightly forward at the hips and to hold their head upright. In this
149 position, they were requested to look straight ahead. Then without bending their back, they
150 were asked to pull as hard as possible on the chain and try to straighten their legs, keeping
151 their arms straight. They pulled against the weight steadily (no jerky movements), keeping
152 the feet flat on the base of the dynamometer. The maximum performance was recorded when
153 their legs were almost straight at the end of the lift. The result from the dynamometer was
154 read after the test. Two attempts were given to the participants and the best score was
155 recorded.

156

157 **2.2.4. Sprint Test**

158 The sprint runs were performed in the indoor futsal court. After a standardized 15-min warm-
159 up period that included low-intensity running, several accelerations runs, and stretching
160 exercises, both Cr and Pl group undertook a sprint running test consisting of three maximal
161 sprints of 10, 20, and 30 m with a 60-s rest period between each test. During the 60-s
162 recovery period, the subjects walked back to the starting line. The running time of the sprints
163 were recorded using Newtest Powertimer 300 photocells (Oulu, Finland). The photocell gates
164 were placed at 10 m, 20 m and 30 m. All distance was run twice and the best time was
165 recorded.

166 **2.2.5. Agility Test**

167 The Illinois agility test (IAT) was used to measure agility during sprints including direction
168 changes without stopping, and running at different angles. This measurement was conducted
169 using Newtest Powertimer 300-series photocells (Oulu, Finland). Participants performed two
170 trials of the agility test with five minutes recovery between trials. The best time of the two
171 trials was recorded to use for statistics.

172 **2.2.6. Statistics Analysis**

173 The statistical analyses were performed using the SPSS version 21.0 software package (SPSS
174 Inc., Chicago, IL, USA). Data are presented as mean \pm SD. ANCOVA with baseline time
175 measurement serving as the covariate in order to test for group differences in agility, strength
176 and sprint tests after Cr supplementation was used to analyze the data. Statistical significance
177 was set at $\alpha \leq 0.05$.

178 **3. Results**

179 Total thirty female futsal players (age: 19.83 ± 1.13 yrs, height: 164.20 ± 6.47 cm, BW:
180 56.23 ± 6.34 kg) agreed to participate in the study and they all completed the study. There
181 were no differences existed among groups at the beginning of the study in terms of age, BW,
182 height, body mass index and training background (Table 1; $p > 0.05$). All subjects reported
183 adherence to the experimental protocol and completed ingestion of the supplement. The
184 results of performance tests applied in the study were demonstrated in Table 2. The results
185 obtained showed that short-term Cr supplementation had no significant effect on BW
186 ($p > 0.05$; Table 2). Along with this, 7 days of Cr supplementation (0.25 g/kg/d) resulted in

187 increasing 10m, 20m, and 30m sprint performance in CrG compared with PIG (0.03; $p < 0.05$,
188 0.30; $p < 0.05$, 0.00; $p < 0.05$, respectively; Figure 1, Table 2).

189 CrG showed statistically significant increase in leg strength when compared to their baseline
190 value (pre: 106.2 ± 13.0 kg, post: 117.9 ± 12.98 kg; $p < 0.05$). Using baseline time measurement
191 serving as the covariate, CrG had higher leg strength compared with PIG's post value (CrG
192 post: 106.2 ± 13.0 kg, PIG post: 81.70 ± 17.29 kg; $p < 0.05$, Table 1, Figure 2).

193

194 After Cr supplementation loading, agility performance in CrG improved statistically
195 significant compared with both their baseline value (pre: 18.33 ± 0.92 sec, post: 17.60 ± 0.88
196 sec; $p < 0.05$, Figure 3) and PIG post value (CrG post: 17.60 ± 0.88 sec, PIG post: 16.72 ± 0.34 sec;
197 $p < 0.05$, Figure 3).

198 **4. Discussion**

199 The major findings of this study were that short-term CrM supplementation improved
200 multiple sprints, agility and leg strength performance in female futsal players following 7
201 days of loading without an associated increase in BW. Although direct measurement of
202 muscle Cr was not done, the reported compliance of subject to a proven Cr loading protocol
203 provides indirect support of the success of our supplementation protocol. While there is only
204 one study published so far where authors aimed to know the effect of long-term Cr
205 supplementation in female players (12), to our knowledge, we are the first to assess the
206 efficacy of short-term Cr supplementation on performance in female futsal players
207 performing a sports-specific activity.

208 The substantial results obtained in this study provide that Cr supplementation can be used by
209 female athletes to improve physical performance. Our results are consistent with other
210 existing studies on Cr supplementation, showing the ergogenic effect of Cr supplementation
211 on exercise performance (14-16). In a review prepared by Miny and et al. related to Cr
212 supplementation in soccer, it has been clearly suggested that Cr loading may be an effective
213 strategy to enhance performances including muscle strength, sprint, and vertical jump (17).

214 In this study, Cr supplementation significantly improved sprint performance in 10m, 20m,
215 and 30m. These results are similar to previous findings (8, 18, 19). Some groups have failed
216 to find improvements in the repeated sprint performance after Cr loading (20, 21). This
217 discrepancy may be attributed to the difference in the experimental design and the choice of

218 the performance outcome. The results obtained in this study showed that acute Cr
219 supplementation provides a potential benefit in energy provision during very short-term,
220 high-intensity exercise. This may be the reason of the increase in sprint performance after
221 loading Cr. In addition, another mechanism that should be emphasized here is that expected
222 increase in muscle PCr after loading Cr supplementation, which was shown in a study
223 conducted by Casey (22). This would have been an effect on sprint performance. In a detailed
224 consensus statement on Cr supplementation by Terjung and et al. (2000) demonstrated that an
225 increase in PCr ranging from 10–20% achieved by Cr supplementation may contribute to
226 improving performance during a 30-s sprint due to the 2.5–5% increase in energy supply
227 (18). These findings explain the improvements seen in sprint performance in this study after
228 loading Cr supplementation.

229 Agility performance test time was shorter in the CrG compared to both CrG baseline value
230 and PiG post after loading. These findings of improved performance in agility test are one of
231 the most important part of loading Cr supplementation when taking into account that futsal
232 players have to achieve high-intensity activity during the game. As being similar to our
233 finding, some studies reported an increase in agility test performance after Cr loading (10,
234 23). A study conducted by van Leemputte and et al., (1999) demonstrated that increase in
235 intracellular stores of PCr would lead to improved efficiency of sarcoplasmic Ca^{++} -ATPase
236 activity and cross-bridge cycling, thereby decreasing the energy costs of human skeletal
237 muscle relaxation (24). As a result of these adaptations, power production by skeletal muscle
238 would increase and maximal high-intensity muscular contractions could be sustainable for a
239 greater period of time (24). According to this theory, mechanisms underlying these effects
240 would facilitate the rapid and repeated muscle actions required agility, leading to an enhanced
241 performance in agility performance (23).

242 Other physiological parameter measured after Cr supplementation was leg strength of the
243 participants. The results showed that Cr supplementation resulted in increasing in leg
244 strength. These results are consistent with those studies showing the effects of Cr on strength
245 (19, 23, 25). In a study conducted by Brose and et al. (2003), it was found efficacy of Cr on
246 strength (26). Another study conducted by Urbaski and et al., (1999) observed an increase in
247 maximal isometric leg strength following 7 days of Cr supplementation (25gr/kg/d) (27).
248 Wiroth and et al., (2001) showed an increase in maximal strength after 5 days of Cr loading
249 (19). After Cr loading, this observed increase can be attributed to increasing in the level of

250 PCr in muscle (28). This assumption was supported by a study where vastus lateralis muscle
251 taken, showing this expected increase in PCr after Cr loading (22).

252 With few exceptions including the current one, almost all studies so far conducted have
253 reported increases in BW of 0.5–3.0 kg after Cr supplementation (7, 8, 29-33), some studies
254 have not (34-38). Possible reason behind this discrepancy may be explained with different
255 loading protocols applied in a different population. It is well known that a possible
256 mechanism underlying the short-term Cr-induced increase in BW is associated with the
257 increases in water retention in the intramuscular space as a result of the cellular transport of
258 Cr with Na⁺ (39) or a creatine-stimulated increase in myofibrillar protein synthesis (40).
259 However, short-term Cr loading applied in the current one didn't cause an increase in BW in
260 this study as seen. This may be explained with the training during the supplementation, which
261 may have been too intense and high in volume to allow sufficient gain in BW.

262 **6. Conclusion**

263 Cr supplementation used by athletes engaged in multiple sprint events, such as soccer and
264 other team sports has become popular recently. Due to its specific characteristic, futsal
265 performance that contains high intensity and short-term movement without resting period,
266 can be improved by loading Cr. Additionally, the effect seen in football players after Cr
267 supplementation cannot be generalized to futsal players because of the difference between
268 football and futsal. Taking into account all of these, to our knowledge, we are the first to
269 show the effects of short-term (7-days) Cr supplementation on physical performance in
270 female futsal players. In conclusion, short-term Cr supplementation (0.25 gr/kg/d) is
271 effective for increasing performance in female futsal players following 7 days of loading
272 without an associated increase in BW.

273 **Funding statement**

274 This research did not receive any specific grant from funding agencies in the public,
275 commercial, or not-for-profit sectors.

276

277 **Conflict of Interest**

278 The authors declare that they have no competing interest.

279

280

281

282 **Acknowledgments**

283 Many thanks to participants of female futsal team members and the team trainer. Also, we
284 appreciate to Assoc. Prof. Dr. H.Husrev Turnagol and Assoc. Prof. Dr. S. Nazan Kosar for
285 their skilful reading of the manuscript.

286

287

288

289

290

291

292

293

294

295

296

297

298

299

300

301

302

303

304

305

306

307

308

309

310

311

312

313

314

315

316

317

318

319

320

321

322
323
324
325
326
327
328
329

References

- 330 1. Galy O, Zongo P, Chamari K, Chaouachi A, Michalak E, Dellal A, et al. Anthropometric and
331 physiological characteristics of Melanesian futsal players: a first approach to talent identification in
332 Oceania. *Biology of sport*. 2015;32(2):135-41.
- 333 2. Dogramaci SN, Watsford ML. A comparison of two different methods for time-motion
334 analysis in team sports. *International Journal of Performance Analysis in Sport*. 2006;6(1):73-83.
- 335 3. Little T, Williams AG. Specificity of acceleration, maximum speed, and agility in
336 professional soccer players. *Journal of strength and conditioning research / National Strength &
337 Conditioning Association*. 2005;19(1):76-8.
- 338 4. Vaeyens R, Lenoir M, Williams AM, Philippaerts RM. Mechanisms underpinning successful
339 decision making in skilled youth soccer players: an analysis of visual search behaviors. *Journal of
340 motor behavior*. 2007;39(5):395-408.
- 341 5. Hultman E, Greenhaff PL. Skeletal muscle energy metabolism and fatigue during intense
342 exercise in man. *Science progress*. 1991;75(298 Pt 3-4):361-70.
- 343 6. Wallimann T, Wyss M, Brdiczka D, Nicolay K, Eppenberger HM. Intracellular
344 compartmentation, structure and function of creatine kinase isoenzymes in tissues with high and
345 fluctuating energy demands: the 'phosphocreatine circuit' for cellular energy homeostasis. *The
346 Biochemical journal*. 1992;281 (Pt 1):21-40.
- 347 7. Claudino JG, Mezencio B, Amaral S, Zanetti V, Benatti F, Roschel H, et al. Creatine
348 monohydrate supplementation on lower-limb muscle power in Brazilian elite soccer players. *J Int Soc
349 Sports Nutr*. 2014;11:32.
- 350 8. Izquierdo M, Ibanez J, Gonzalez-Badillo JJ, Gorostiaga EM. Effects of creatine
351 supplementation on muscle power, endurance, and sprint performance. *Medicine and science in sports
352 and exercise*. 2002;34(2):332-43.
- 353 9. Ostojic SM. Creatine supplementation in young soccer players. *International journal of sport
354 nutrition and exercise metabolism*. 2004;14(1):95-103.
- 355 10. Cox G, Mujika I, Tumilty D, Burke L. Acute creatine supplementation and performance
356 during a field test simulating match play in elite female soccer players. *International journal of sport
357 nutrition and exercise metabolism*. 2002;12(1):33-46.
- 358 11. Human Fazli MM, Fazlollah Azizi. Effect of creatine supplementation on physiological
359 demands and skill performance of futsal players *The International Journal of Current Research and
360 Academic Review* 2014;2(9):62-7.
- 361 12. Halit H, Arslan K, Mihri B, Aydın Ş. Effects of Creatine Supplementation on Motor
362 Performance in Female Futsal Players. *The Online Journal of Recreation and Sport*. 2013;2(4):22-8.
- 363 13. Sale C, Harris RC, Florance J, Kumps A, Sanvura R, Poortmans JR. Urinary creatine and
364 methylamine excretion following 4 x 5 g x day(-1) or 20 x 1 g x day(-1) of creatine monohydrate for 5
365 days. *Journal of sports sciences*. 2009;27(7):759-66.
- 366 14. Barber JJ, McDermott AY, McGaughey KJ, Olmstead JD, Hagobian TA. Effects of combined
367 creatine and sodium bicarbonate supplementation on repeated sprint performance in trained men.

368 Journal of strength and conditioning research / National Strength & Conditioning Association.
369 2013;27(1):252-8.

370 15. Hespel P, Maughan RJ, Greenhaff PL. Dietary supplements for football. Journal of sports
371 sciences. 2006;24(7):749-61.

372 16. Peyrebrune MC, Nevill ME, Donaldson FJ, Cosford DJ. The effects of oral creatine
373 supplementation on performance in single and repeated sprint swimming. Journal of sports sciences.
374 1998;16(3):271-9.

375 17. Miny K, Burrowes J, Jidovtseff B. Interest of creatine supplementation in soccer. Science &
376 Sports. 2017;32(2):61-72.

377 18. Terjung RL, Clarkson P, Eichner ER, Greenhaff PL, Hespel PJ, Israel RG, et al. American
378 College of Sports Medicine roundtable. The physiological and health effects of oral creatine
379 supplementation. Medicine and science in sports and exercise. 2000;32(3):706-17.

380 19. Wiroth JB, Bermon S, Andrei S, Dalloz E, Hebuterne X, Dolisi C. Effects of oral creatine
381 supplementation on maximal pedalling performance in older adults. Eur J Appl Physiol.
382 2001;84(6):533-9.

383 20. Glaister M, Lockey RA, Abraham CS, Staerck A, Goodwin JE, McInnes G. Creatine
384 supplementation and multiple sprint running performance. Journal of strength and conditioning
385 research / National Strength & Conditioning Association. 2006;20(2):273-7.

386 21. Tarnopolsky MA, MacLennan DP. Creatine monohydrate supplementation enhances high-
387 intensity exercise performance in males and females. International journal of sport nutrition and
388 exercise metabolism. 2000;10(4):452-63.

389 22. Casey A, Constantin-Teodosiu D, Howell S, Hultman E, Greenhaff PL. Creatine ingestion
390 favorably affects performance and muscle metabolism during maximal exercise in humans. Am J
391 Physiol. 1996;271(1 Pt 1):E31-7.

392 23. Camic CL, Kovacs AJ, Enquist EA, VanDusseldorp TA, Hill EC, Calantoni AM, et al. An
393 electromyographic-based test for estimating neuromuscular fatigue during incremental treadmill
394 running. Physiological measurement. 2014;35(12):2401-13.

395 24. van Leemputte M, Vandenbergh K, Hespel P. Shortening of muscle relaxation time after
396 creatine loading. Journal of applied physiology (Bethesda, Md : 1985). 1999;86(3):840-4.

397 25. Hespel P, Op't Eijnde B, Leemputte MV, Ursø B, Greenhaff PL, Labarque V, et al. Oral
398 creatine supplementation facilitates the rehabilitation of disuse atrophy and alters the expression of
399 muscle myogenic factors in humans. The Journal of Physiology. 2001;536(2):625-33.

400 26. Brose A, Parise G, Tarnopolsky MA. Creatine supplementation enhances isometric strength
401 and body composition improvements following strength exercise training in older adults. J Gerontol A
402 Biol Sci Med Sci. 2003;58(1):11-9.

403 27. Urbanski RL, Vincent WJ, Yaspelkis BB, 3rd. Creatine supplementation differentially affects
404 maximal isometric strength and time to fatigue in large and small muscle groups. Int J Sport Nutr.
405 1999;9(2):136-45.

406 28. Harris RC, Soderlund K, Hultman E. Elevation of creatine in resting and exercised muscle of
407 normal subjects by creatine supplementation. Clin Sci (Lond). 1992;83(3):367-74.

408 29. Becque MD, Lochmann JD, Melrose DR. Effects of oral creatine supplementation on
409 muscular strength and body composition. Medicine and science in sports and exercise.
410 2000;32(3):654-8.

411 30. Gilliam JD, Hohzorn C, Martin D, Trimble MH. Effect of oral creatine supplementation on
412 isokinetic torque production. Medicine and science in sports and exercise. 2000;32(5):993-6.

413 31. Haff GG, Kirksey KB, Stone MH, Warren BJ, Johnson RL, Stone MEG, et al. The Effect of 6
414 Weeks of Creatine Monohydrate Supplementation on Dynamic Rate of Force Development. Journal
415 of Strength and Conditioning Research. 2000;14(4):426-33.

- 416 32. Kinugasa R, Akima H, Ota A, Ohta A, Sugiura K, Kuno SY. Short-term creatine
417 supplementation does not improve muscle activation or sprint performance in humans. *Eur J Appl*
418 *Physiol.* 2004;91(2-3):230-7.
- 419 33. Volek JS, Ratamess NA, Rubin MR, Gomez AL, French DN, McGuigan MM, et al. The
420 effects of creatine supplementation on muscular performance and body composition responses to
421 short-term resistance training overreaching. *Eur J Appl Physiol.* 2004;91(5-6):628-37.
- 422 34. Antonio J, Ciccone V. The effects of pre versus post workout supplementation of creatine
423 monohydrate on body composition and strength. *J Int Soc Sports Nutr.* 2013;10:36.
- 424 35. Chilibeck PD, Magnus C, Anderson M. Effect of in-season creatine supplementation on body
425 composition and performance in rugby union football players. *Applied physiology, nutrition, and*
426 *metabolism = Physiologie appliquee, nutrition et metabolisme.* 2007;32(6):1052-7.
- 427 36. Earnest CP, Almada AL, Mitchell TL. High-performance capillary electrophoresis-pure
428 creatine monohydrate reduces blood lipids in men and women. *Clin Sci (Lond).* 1996;91(1):113-8.
- 429 37. Francaux M, Demeure R, Goudemant JF, Poortmans JR. Effect of exogenous creatine
430 supplementation on muscle PCr metabolism. *Int J Sports Med.* 2000;21(2):139-45.
- 431 38. Rawson ES, Stec MJ, Frederickson SJ, Miles MP. Low-dose creatine supplementation
432 enhances fatigue resistance in the absence of weight gain. *Nutrition.* 2011;27(4):451-5.
- 433 39. Hultman E, Soderlund K, Timmons JA, Cederblad G, Greenhaff PL. Muscle creatine loading
434 in men. *Journal of applied physiology (Bethesda, Md : 1985).* 1996;81(1):232-7.
- 435 40. Jacobs I, Bleue S, Goodman J. Creatine ingestion increases anaerobic capacity and maximum
436 accumulated oxygen deficit. *Canadian journal of applied physiology = Revue canadienne de*
437 *physiologie appliquee.* 1997;22(3):231-43.

438