SPRINT MECHANICAL PROPERTIES OF PROFESSIONAL SOCCER PLAYERS DURING A MATCH SIMULATION

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The purpose of this study was to identify soccer-specific changes of mechanical properties in sprinting during a simulated soccer match. Professional soccer players (n=15) completed six sprint measurements before, during and after a simulated soccer game (i.e. Copenhagen Soccer Test). Mechanical properties (theoretical maximal sprinting velocity (V0), theoretical maximal horizontal force (F0), maximal horizontal sprinting power (Pmax) and the 20-metre sprint time were computed from continuous velocity data captured from a laser device. The results suggest that soccer-specific fatigue affects V0 more than F0. Furthermore, there is an inactivity-induced sprint performance loss because of the half-time break. However, at the end of the game, professional players can achieve similar sprint times as in the first half. These results could be useful for effective training planning and optimizing sprint performance during a match.

KEYWORDS: power-force-velocity-profiling, sprint, fatigue, soccer, professional.

INTRODUCTION: Athletic requirements, in particular sprinting ability, have increased in professional soccer in recent years (Barnes et al., 2014). Sprint times during actual and simulated soccer matches for amateur, highly-trained and semi-professional players are impaired towards the end of a match (Bendiksen et al., 2012; Fransson et al., 2018; Krustrup et al., 2006; Mohr et al., 2004; Small et al., 2009). However, sprint performance can be better described with an additional analysis of sprint mechanical properties compared to only reporting the sprint times (Buchheit et al., 2014). These properties can be collected by horizontal power-force-velocity (P-F-v) profiling (Morin & Samozino, 2016). In addition to sprint time, the theoretical maximal horizontal force output (F0), theoretical maximal running velocity (V0) and maximal horizontal mechanical power output (Pmax = F0 x V0 / 4) can be computed. To date, one study has examined changes in mechanical determinants during a soccer match (Nagahara et al., 2016). Thirteen non-professional college soccer players completed sprints immediately before the start of the game, after the first half, before the start of the second half and after the second half. V0, Pmax and 20-metre sprint time showed global effects, but not F0. 20-metre sprint time increased significantly by 2.4% from the end of the first half to the beginning of the second half. V0 decreased significantly by 3.9% from the beginning to the end of the match. However, sprint performance and repeated sprint ability distinguishes professional from non-professional players (Haugen et al., 2013; Rampinini et al., 2009). Therefore, these findings may not be transferable to professional soccer players. Furthermore, Nagahara et al. (2016) collected players' data only before and after each half. Thus, it is not possible to determine how the mechanical parameters evolved during half-time. Another limitation of the study can be seen in the friendly match setting, where the problem of high game-to-game- and position variability does occur (Gregson et al., 2010). In order to ensure the same activities and regeneration before each sprint measurement for every athlete, a simulated soccer game, for example the Copenhagen-Soccer-Test (Bendiksen et al., 2012), would be a superior study approach.
The aim of this study was to investigate the changes in sprinting performance and mechanical properties of professional soccer players before, during and after a simulated soccer match to gather detailed insights and understanding of the development of the sprint profile in professional athletes.

METHODS: Fifteen male professional field soccer players (age: 19.7 ± 2.1 yrs; height: 177.7 ± 6.6 cm; mass: 71.9 ± 6.9 kg) of the second Austrian soccer league participated in the study. The testing took place in spring 2019. The experimental protocol consisted of a simulated soccer match, the Copenhagen Soccer Test (CST) (Bendiksen et al., 2012), and six 40-meter-sprint measurements before, during and after each half.

The CST is a 2x45-minute soccer-specific test with a 15-minute half-time break, which imitates the activities of real competitive elite soccer games. The subjects performed passive recovery between the halves. The physiological response of this simulation test is reproducible and comparable to that of a competitive game (Bendiksen et al., 2012). The subjects performed six maximum intensity 40-meter sprints at minute 1, 25, 45, 46, 70 and 90 of the CST. The athletes were captured by a laser distance measurement system (LDM 301, Jenoptik, Jena, Germany; sampling rate, 100Hz) to compute V0, $F0_{rel}$, $Pmax_{rel}$ (“rel” refers to normalised to body mass) and 20-metre sprint time in accordance with Samozino et al. (2016).

For V0, $F0_{rel}$, $Pmax_{rel}$ and 20-m sprint time paired sample t-Tests were used to detect differences from the start to the end of the game (1’ to 90’) as well as differences before and after half-time break (45’ to 46’). To test differences within each half two ANOVAs (1x3) with repeated measures for the first (1’, 25’, 45’) and second half (46’, 70’, 90’) were performed for V0, $F0_{rel}$, $Pmax_{rel}$ and 20-m sprint time. In case of global significance, Bonferroni corrected post hoc tests were applied. Effect size was determined by partial eta squared (η^2) and according to the limits for the size of the effect are .01, .06 and .14 for small, medium and large. The statistical level of significance was set at $P < .05$ and tendency at P from 0.1 to 0.05.

RESULTS: V0 decreased significantly (P=.016) from 1’ to 90’. From 45’ to 46’ (half-time break) the 20m-time (P=.003), $F0_{rel}$ (P=.006) and $Pmax_{rel}$ (P=.003) deteriorated significantly.

Within the first half significant and large effects on V0 (n=15, p=.002, η^2=.35, power=.919) were observed. The post hoc analysis revealed that V0 was significantly higher in the first minute than in the 45th minute (P=.011) and tended to be higher from 1’ to 25’ (P=.09).

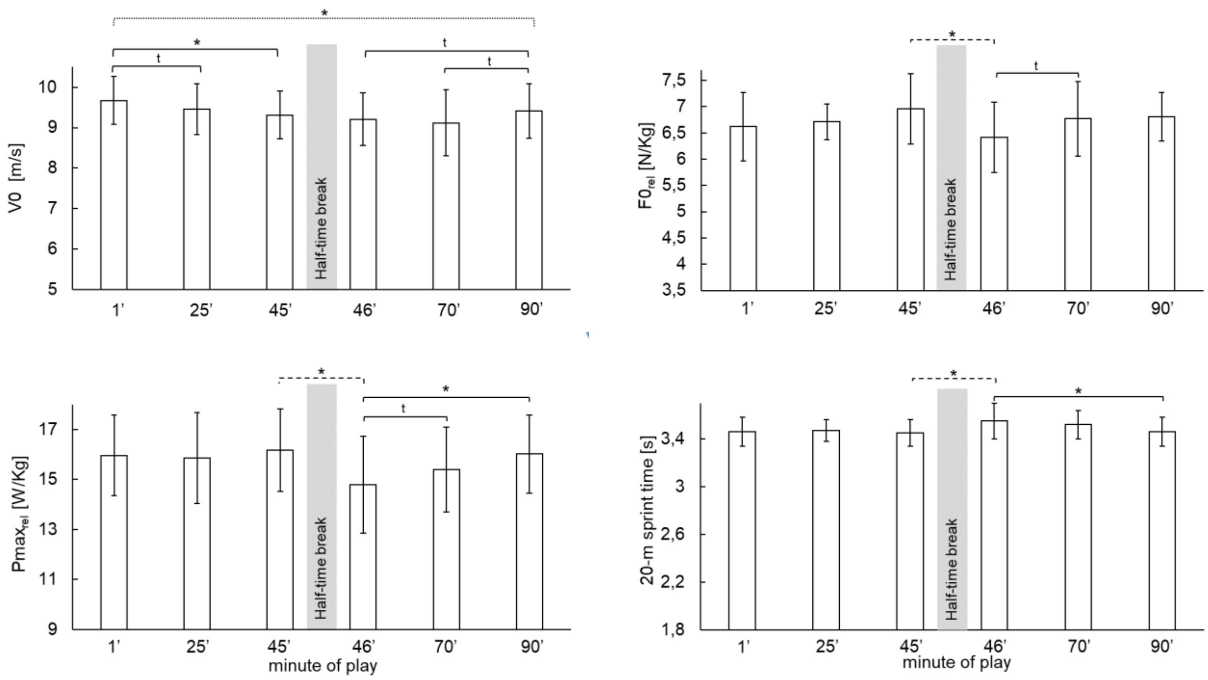

Figure 1: The change of V0, $F0_{rel}$, $Pmax_{rel}$ and the 20-m time during the CST. Solid line represents the post hoc tests of the ANOVA, dotted line represents the results of the t tests from the first to the 90th minute and dashed line represents the t test from the 45th to the 46th.

Within the second half significant and consistently large effects for the 20-m sprint times (n=15, p=.002, η^2=.37, power=.94), V0 (n=15, p=.03, η^2=.22, power=.666), $F0_{rel}$ (n=15, p=.032, η^2=.218, power= .657) and $Pmax_{rel}$ (n=15, p=.005, η^2=.32, power=.878) were observed. Post hoc tests indicated significant decreases in 20-m sprint time from 46’ to 90’ (p=.009); for V0 a tendency to increase from 46’ to 90’ (p=.092) as well as from 70’ to 90’ (p=.069); for $F0_{rel}$ a tendency from 46’ to 70’ (p=.053); and for $Pmax_{rel}$ a significance from 46’ to 90’ (p=.023) as well as a tendency from 46’ to 70’ (p=.097).

DISCUSSION: The aim of this study was to clarify if and how the mechanical parameters of sprinting ability in football professionals change during a simulated soccer game. So far, most studies have determined fatigue based on changes in pure sprint times (Krustrup et al., 2006; Mohr et al., 2004; Small et al., 2009). Horizontal P-F-v profiling allows a more detailed assessment of sprint performance.
The paired t-Test from the first to the 90^{th} minute showed significant impairments for V0 by 2.69%, which are less than the 3.9% decrement in non-professional players observed by Nagahara et al. (2016). This decrease of V0 could be due to a lower functional capability of the hamstrings. For soccer specific fatigue, eccentric knee flexion force (Greig, 2008), knee extension angle, and maximal hip flexion is reduced, indicating lowered hamstring capacity (Small et al., 2009). Like Nagahara et al. (2016), in this study only a deterioration of V0 and no change in $F0_{rel}$ from the first to the 90th minute was observed, which illustrates the influence of soccer specific fatigue on V0 and $F0_{rel}$.
The 2.9% increase in sprint time from the end of the first half to the beginning of the second half is comparable to the 2.4% increase of Nagahara et al. (2016). As with Nagahara et al. (2016), $Pmax_{rel}$ deteriorated during the half-time break, from the 45^{th} to the 46^{th} minute of the game. The observed reduction (8.5%) was higher than the 5.8% of Nagahara et al. (2016).
These deteriorations could potentially be explained due to the lower muscle temperature caused by inactivity and could be reversed by a seven-minute re-warm-up at moderate intensity (Mohr et al., 2004). Because $F0_{rel}$ decreased significantly during half-time and V0 did not (7.7% vs 1.1%), the inactivitiy-induced decrease of the muscle temperature appears to have a greater influence on the initial sprint acceleration than on the maximal running speed.
The ANOVA for the first half showed large effects for V0 and a significant impairment by 3.7% from the first to the 45^{th} minute and tended to decrease from the first to the 25^{th} (2.17%), which were not observed by Nagahara et al. (2016). Within the second half, large effects for all four parameters were shown. The 20-m time decreased from the 46^{th} to the 90^{th} minute (2.54%) and the sprint time of the 90^{th} minute (3.46 ± .12 s) is in the range of the sprint times of the first half (3.46 ± .12, 3.47 ± .09 and 3.45 ± .11 s). The sprint time in the 90^{th} minute could be seen as a specific quality of professional players, since non-professionals showed impairments in sprint times by 2.0 to 2.8% at the end of a match compared to the start (Krustrup et al., 2006; Mohr et al., 2004; Nagahara et al., 2016). The sprint time in the 90^{th} minute can be explained due to a better V0 (2.17%) - which tended to improve - and – though statistically non-significant – $F0_{rel}$ (6.07%). Furthermore, $F0_{rel}$ tended to increase from the 46^{th} to the 70^{th} (5.45%). As in the study of Nagahara et al. (2016), it seems that $F0_{rel}$ improved within each half. The muscle temperature, which in turn is a factor of post-activation performance enhancement (Blazevich & Babault, 2019), could have a positive effect on $F0_{rel}$ within each half. V0 tended to increase from the 46^{th} to the 90^{th} and from the 70^{th} to the 90^{th} (3.18%) but differs significantly compared to the start of the game. These potential improvements can be caused by a higher motivation for the last sprint. In addition, a soccer game, i.e. Copenhagen Soccer Test, could be a stimulus which is not entireley maximal for professional male soccer players, so in a status of quasi fatigue - e.g. in the 90th minute - they are able to sprint the same 20-m time as in the first half. For a detailed and individualized training programming, mechanical characteristics and 20-m sprint time could be further analyzed on an individual level to identify possible weaknesses in fatigued and non-fatigued states for each player. This is a potential field of practical application of the CST for regular testing in professional soccer players, potentially combining mechanical (e.g. P-F-v-profiling) and physiological (e.g. VO2 and lactate) aspects.

CONCLUSION: This study provides new insights into the complexity of fatigue and sprint performance in professional football during a simulated soccer match. It has been demonstrated that soccer-specific exercise has an influence on the mechanical properties of sprinting ability. Game-specific loading impaired maximum running speed throughout the match. Furthermore, the observed reduction in sprint performance after half-time break may be attributed to a reduction in muscle temperature and knee flexion capability because of the half-time break inactivity. Compared to non-professional players, it seems that professional players at the end of the game can achieve again similar sprint times as in the first half. These new insights are useful for coaches, as they provide how sprinting ability changes during soccer matches, so training and matches can be planned effectively.

REFERENCES

Barnes, C., Archer, D. T., Hogg, B., Bush, M., & Bradley, P. S. (2014). The evolution of physical and technical performance parameters in the English Premier League. *Int J Sports Med, 35*(13), 1095-1100. doi:10.1055/s-0034-1375695

Bendiksen, M., Bischoff, R., Randers, M. B., Mohr, M., Rollo, I., Suetta, C., Bangsbo, J., & Krustrup, P. (2012). The Copenhagen Soccer Test: physiological response and fatigue development. *Med Sci Sports Exerc, 44*(8), 1595-1603. doi:10.1249/MSS.0b013e31824cc23b

Blazevich, A. J., & Babault, N. (2019). Post-activation Potentiation Versus Post-activation Performance Enhancement in Humans: Historical Perspective, Underlying Mechanisms, and Current Issues. *Front Physiol, 10*(1359). doi:10.3389/fphys.2019.01359

Buchheit, M., Samozino, P., Glynn, J. A., Michael, B. S., Al Haddad, H., Mendez-Villanueva, A., & Morin, J. B. (2014). Mechanical determinants of acceleration and maximal sprinting speed in highly trained young soccer players. *J Sports Sci, 32*(20), 1906-1913. doi:10.1080/02640414.2014.965191

Fransson, D., Vigh-Larsen, J. F., Fatouros, I. G., Krustrup, P., & Mohr, M. (2018). Fatigue Responses in Various Muscle Groups in Well-Trained Competitive Male Players after a Simulated Soccer Game. *J Hum Kinet, 61*, 85-97. doi:10.1515/hukin-2017-0129

Gregson, W., Drust, B., Atkinson, G., & Salvo, V. D. (2010). Match-to-match variability of high-speed activities in premier league soccer. *Int J Sports Med, 31*(4), 237-242. doi:10.1055/s-0030-1247546

Greig, M. (2008). The influence of soccer-specific fatigue on peak isokinetic torque production of the knee flexors and extensors. *Am J Sports Med, 36*(7), 1403-1409. doi:10.1177/0363546508314413

Haugen, T. A., Tonnessen, E., & Seiler, S. (2013). Anaerobic performance testing of professional soccer players 1995-2010. *Int J Sports Physiol Perform, 8*(2), 148-156.

Krustrup, P., Mohr, M., Steensberg, A., Bencke, J., Kjaer, M., & Bangsbo, J. (2006). Muscle and Blood Metabolites during a Soccer Game: Implications for Sprint Performance. *Med Sci Sports Exerc, 38*(6), 1165-1174. doi:10.1249/01.mss.0000222845.89262.cd

Mohr, M., Krustrup, P., Nybo, L., Nielsen, J. J., & Bangsbo, J. (2004). Muscle temperature and sprint performance during soccer matches--beneficial effect of re-warm-up at half-time. *Scand J Med Sci Sports, 14*(3), 156-162. doi:10.1111/j.1600-0838.2004.00349.x

Morin, J.-B., & Samozino, P. (2016). Interpreting Power-Force-Velocity Profiles for Individualized and Specific Training. *Int J Sports Physiol Perform, 11*(2), 267-272. doi:10.1123/ijspp.2015-0638

Nagahara, R., Morin, J.-B., & Koido, M. (2016). Impairment of Sprint Mechanical Properties in an Actual Soccer Match: A Pilot Study. *Int J of Sports Physiol & Perform, 11*(7), 893-898.

Rampinini, E., Sassi, A., Morelli, A., Mazzoni, S., Fanchini, M., & Coutts, A. J. (2009). Repeated-sprint ability in professional and amateur soccer players. *Appl Physiol Nutr & Me, 34*(6), 1048-1054.

Samozino, P., Rabita, G., Dorel, S., Slawinski, J., Peyrot, N., Saez de Villarreal, E., & Morin, J. B. (2016). A simple method for measuring power, force, velocity properties, and mechanical effectiveness in sprint running. *Scand J Med Sci Sports, 26*(6), 648-658. doi:10.1111/sms.12490

Small, K., McNaughton, L. R., Greig, M., Lohkamp, M., & Lovell, R. (2009). Soccer fatigue, sprinting and hamstring injury risk. *Int J Sports Med, 30*(8), 573-578. doi:10.1055/s-0029-1202822