SOCCER SEASONAL VARIATIONS IN SPRINT MECHANICAL PROPERTIES AND VERTICAL JUMP PERFORMANCE

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Abstract:

The aim of this study was to quantify possible differences in countermovement jump (CMJ) height, sprint performance and underlying mechanical properties as a function of time during a soccer season. Forty-four male professional soccer players were identified in the Norwegian Olympic Federation's test database. Each of these players had performed 40-m sprint and CMJ tests at least once within pre-season, in-season and off-season over the course of one year. The players sprinted, possibly to most likely, faster over 40 m during off-season compared to in-season (mean difference, ±90%CL: 0.04, ±0.03 s; small) and pre-season (0.08, ±0.02 s; small). Maximal horizontal power production was likely to most likely greater off-season compared to in-season (mean difference, ±90%CL: 0.5, ±0.4 $W \cdot kg^{-1}$; small) and pre-season (0.8, ±0.4 $W \cdot kg^{-1}$; small). Maximal horizontal force production was likely greater off-season compared to in-season (0.2, ±0.2 $N \cdot kg^{-1}$; small). Theoretical maximal velocity obtained during pre-season was, possibly to very likely, lower compared to in-season (0.09, ±0.12 $m \cdot s^{-1}$; small) and off-season (0.14, ±0.09 $m \cdot s^{-1}$; small). The force-velocity slope values relative to body mass were, possibly to likely, higher off-season compared to in-season (0.02, ±0.03; small) and pre-season (0.01, ±0.02; small). CMJ results obtained off-season were, likely better, than those for pre-season (1.2, ±0.6 cm; small). The present study shows that anaerobic fitness variables, believed to be relevant for the on-field soccer performance, are sensitive to the varying season times.

Key words: *accelerated sprinting, maximal velocity sprinting, horizontal power production, force-velocity profile*

Introduction

Sprint and vertical jump capabilities are fundamental parts of the motor skill requirements in soccer to win duels, defend or create goal-scoring chances. Straight sprinting and jumps are frequent actions prior to goals, both for the scoring and assisting player (Faude, Koch, & Meyer, 2012). Both acceleration and maximal velocity sprinting distinguish soccer players of varying standards of play (Haugen, Tønnessen, & Seiler, 2012[A], 2013). Professional players have become faster over time, indicating that sprinting skills are becoming more and more important in modern soccer (Haugen, et al., 2013). Total sprint distance and number of sprints undertaken during games increased by ~35% and ~85% in English Premier League players from the season 2006/07 compared to 2012/13 (Barnes, Archer, Hogg, Bush, & Bradley, 2014).

Sprinting in soccer has a dueling aspect, and the ability to either create or close small gaps can be the difference between winning and losing the game. It is therefore crucial for practitioners to possess knowledge regarding the seasonal fluctuations in fundamental motor skills. While seasonal variations in aerobic endurance have been well explored (e.g., Silva, et al., 2011; Tønnessen, Hem, Leirstein, Haugen, & Seiler, 2013; Mohr & Krustrup, 2014), literature is limited and contradictory regarding the potential sprint and vertical jump performance differences through a soccer training year and competition season. Kraemer et al. (2004) reported a significant decrease in 20-yard sprint (~4%) and vertical jump performance (~14%) in collegiate players in-season compared to the baseline test performed one week prior to the first competitive game. However, these decrements were only observed in starters (n=11) and not in non-starters (n=14). Caldwell and Peters (2009) observed that 13 semiprofessional English players achieved superior sprint and vertical jump test results at the end of season compared to the end of off-season (~3 and ~5%, respectively). Requena et al. (2017) reported no significant effects of a 6-week standardized off-season period in 15- and 30-m sprint and vertical jump performance among 19 professional players. Fessi et al. (2016) observed enhanced sprint (~4%) and countermovement jump (CMJ) performance (~11%) test scores as a result of pre-season conditioning in 19 Tunisian professionals, and these qualities were preserved throughout the competitive season. Indeed, more studies of larger cohorts of soccer players are needed to get a clearer picture of the magnitudes of seasonal variations in sprint and vertical jump capabilities.

In recent years, an increasing number of studies have paid attention to underlying mechanical determinants of sprint performance, as such variables provide insights into individual biomechanical limitations (Morin, et al., 2012; Buchheit, et al., 2014; Rabita, et al., 2015). A field method has been developed to calculate mechanical outputs and develop horizontal profiles of accelerated sprinting (Samozino, et al., 2016; Morin & Samozino, 2016). Theoretical maximal velocity (V0), horizontal force (F0), horizontal power (P0) and force-velocity slope can be calculated from modelling by the derivation of the speed-time curve that leads to horizontal acceleration data. The promising aspect of this approach is an individualized diagnosis and development of individualized conditioning programs that target major limiting factors. No studies to date have quantified potential seasonal variations in sprint mechanical outputs in soccer players.

Hence, the aim of this study was to quantify possible differences in countermovement jump (CMJ) height, sprint performance and underlying mechanical properties as a function of time during a soccer season. Such background information is useful for athletes and coaches to properly plan and evaluate their conditioning strategies.

Methods

Data collection

The Norwegian Olympic training center is a standard testing facility for a large number of teams at different performance levels, including national squads. A database of sprint and CMJ results that has been collected over several years provides the potential for addressing questions related to the role of sprint and vertical jump performance in soccer. For the purpose of this study, we identified 44 male players who performed such tests at least once within each of the following periods over the course of one year: pre-season (January 1st – March 31st), in-season (April 1st – October 15th) and off-season (October 15th – December 31st). These seasonal categories were based on the Norwegian competitive season. All identified athletes were professionals and represented six different clubs in the upper Norwegian league. Because this study was based on pre-existing data from quarterly testing that these teams had performed for training purposes, no informed consent was obtained. The Norwegian Olympic Federation approved the use of these data, provided that individual test results remained confidential.

Instruments

All sprint tests were performed on a dedicated indoor 40-metre track with 8 mm Mondotrack FTS surface (Mondo, Conshohocken, USA) and electronic timing equipment. A 60 x 60 cm start pad was placed under the track surface at the start line. The clock was initiated when the front foot stepped off the pad. The athletes' center of gravity was therefore about 50 cm in front of the start line when the timer was initiated. Split times were recorded at 5, 10, 20, 30 and 40 m, providing sufficient data points for mechanical output computations (Samozino, et al., 2016; Morin & Samozino, 2016). Infrared photocells with transmitters and reflectors were placed in pairs on each side of the running course with a 1.6 m transmitter-reflector spacing. The infrared beam was split to reduce the possibility for arms triggering the cells. Transmitters where placed 140 cm above the ground and reflectors for the split beam were placed 130 and 150 cm above the floor. Both beams had to be interrupted to trigger each photo cell. Electronic times were transferred to computer software (Biorun, Biomekanikk AS, Norway). The timing system used in all tests has been validated (Haugen, Tønnessen, & Seiler, 2012B).

To ensure valid sprint mechanical outputs, it is crucial that time initiation (time 0) is very close to the first rise of force production onto the ground (Samozino, et al., 2016; Morin & Samozino, 2016). For the current lift-off procedures with a contact mat, the body's center-of-mass was ~0.5-0.6 m in front of the start line, and with a considerable forward momentum, at time of triggering. Hence, based on available correction factors (Haugen, et al., 2012B; Haugen & Buchheit, 2016), all split times were added 0.5 s for converting to "first movement" triggering.

Countermovement jump tests were performed on a 122 x 62 cm AMTI force platform; model OR6-5-1. Jumping height was determined as the center of mass displacement calculated from the force development and measured body mass. The system setup was in accordance with the guidelines recommended by Street et al. (2001). Force data were sampled at 1000 Hz for five seconds with a resolution of 0.1 N. The data were amplified (AMTI Model SGA6-3), digitized (DT 2801), and saved to the dedicated computer software (Biojump, Biomekanikk AS, Norway). The force platform has been assessed for accuracy and reliability (Enoksen, et al., 2009).

Testing procedures

All tests were performed between 11 a.m. and 6 p.m. at the Olympic training center in Oslo in the time period 2004-2012. Athletes completed a standard warm-up program prior to sprint testing, beginning with 10-15 minutes of easy jog. Then, for

5-6 minutes, they performed sprint-specific drills followed by 2-3 strides with increasing speed. The players completed 1-2 trial starts prior to testing. During testing, athletes assumed the starting position and started running on their own initiative after being cleared to start by the test leader. New trials were performed every 3-5 min until evidence of peak performance was observed. In practice, 80 % of all athletes achieved their best performance within two trials. Best individual 40-m sprint test and accompanying split times were retained for analysis.

Countermovement jump tests were performed 10-15 minutes after the sprint tests. Each athlete was weighed on the force platform for system calibration before testing. All subjects underwent 1-2 easy trial jumps to secure testing procedure familiarization. They then performed 4-6 jumps with 45-60 s recovery between each trial until jump height stabilized. All jumps were performed with the hands placed on the hips. The subjects were required to bend their knees to approximately 90 degrees and then rebound in a maximal vertical jump. Best result for each player was retained for analysis. The entire experimental setting was consistent, and our test results were not affected by other tests. Regarding nutrition, hydration, sleep and physical activity, the athletes were instructed to prepare themselves as they would for a regular competition, including no high-intensity training the last 48 hours before testing. All subjects underwent identical testing procedures and conditions, including equipment and surfaces, during the data collection period.

Statistics

Data are reported as mean ± SD. Shapiro Wilks tests revealed that none of the variables deviated statistically from normal distribution. Coefficient of variation (CV) and intraclass correlation (ICC) were calculated for each variable based on the pre-season testing, using the spreadsheet developed by Hopkins (2015). Magnitudes of differences across category means were assessed by the standardization (mean difference divided by the SD harmonic mean of the compared groups). The thresholds for assessing the observed difference in means were 0.2, 0.6, and 1.2 for small, moderate and large, respectively (Hopkins, Marshall, Batterham, & Hanin, 2009). To make inferences about true values of effects, we used non-clinical magnitude-based inference rather than null-hypothesis significance testing (Hopkins, et al., 2009). Magnitudes were evaluated mechanistically: if the confidence interval overlapped substantial positive and negative values, the effect was deemed unclear; otherwise, effects were deemed clear and shown with the probability that the true effect was either substantial or trivial (whichever was greater) using the following scale: 25-75%, possibly; 75-95%, likely; 95-99.5%, very likely; >99.5%, most likely (Hopkins, et al., 2009).

Results

Table 1. Reliability of all the analyzed variables

Variable	CV (%)	ICC
20-m sprint (s)	0.9	0.96
40-m sprint (s)	0.8	0.98
CMJ (cm)	3.1	0.94
$P0 \cdot kg^{-1}$ ($W \cdot kg^{-1}$)	2.7	0.94
$F0 \cdot kg^{-1}$ ($N \cdot kg^{-1}$)	3.0	0.75
V0 ($m \cdot s^{-1}$)	1.5	0.96
FV-slope$\cdot kg^{-1}$	4.8	0.76

Note. CMJ = countermovement jump, P0 = theoretical maximal power, F0 = theoretical maximal horizontal force, V0 = theoretical maximal velocity, FV = force-velocity.

Table 2. Mean ± SD for all the analyzed variables

Variable	Pre-season	In-season	Off-season
40-m sprint (s)	5.15±0.17	5.11±0.18	5.07±0.15
20-m sprint (s)	2.82±0.09	2.80±0.09	2.77±0.08
CMJ (cm)	37.4±4.0	38.1±4.0	38.6±3.9
Body mass (kg)	79±7	78±6	79±6
P0 (W)	1441±156	1460±166	1502±157
$P0 \cdot kg^{-1}$ ($W \cdot kg^{-1}$)	18.3±1.1	18.6±1.4	19.1±1.4
F0 (N)	649±65	650±62	666±62
$F0 \cdot kg^{-1}$ ($N \cdot kg^{-1}$)	8.2±0.4	8.3±0.4	8.5±0.5
V0 ($m \cdot s^{-1}$)	9.0±0.4	9.0±0.4	9.1±0.3
FV-slope$\cdot kg^{-1}$	-0.92±0.05	-0.92±0.05	-0.93±0.05

Note. CMJ = countermovement jump, P0 = theoretical maximal power, F0 = theoretical maximal horizontal force, V0 = theoretical maximal velocity, FV = force-velocity.

Table 1 shows reliability for all the assessed variables. Table 2 shows mean and SD for the analyzed variables, while Figure 1 shows mean and 90% CL for sprint and CMJ performance as a function of time during a soccer season. Substantial performance differences were observed across the season times. Panel A shows that the players sprinted possibly to most likely faster over 40 m during off-season compared to in-season (mean difference, ±90%CL: 0.04, ±0.03 s; small) and pre-season (0.08, ±0.02 s; small). In-season 40-m sprint results were likely better than those for pre-season (0.05, ±0.03 s; small). Panel B shows that 20-m sprint times off-season were likely to most likely faster than those obtained in-season (0.03, ±0.01 s; small) and pre-season (0.05, ±0.01 s; small. In-season 20-m sprint results were possibly better than those for pre-season (0.02, ±0.01 s; small). Panel C shows that CMJ results obtained off-season were likely better than those for pre-season (1.2, ±0.6 cm; small).

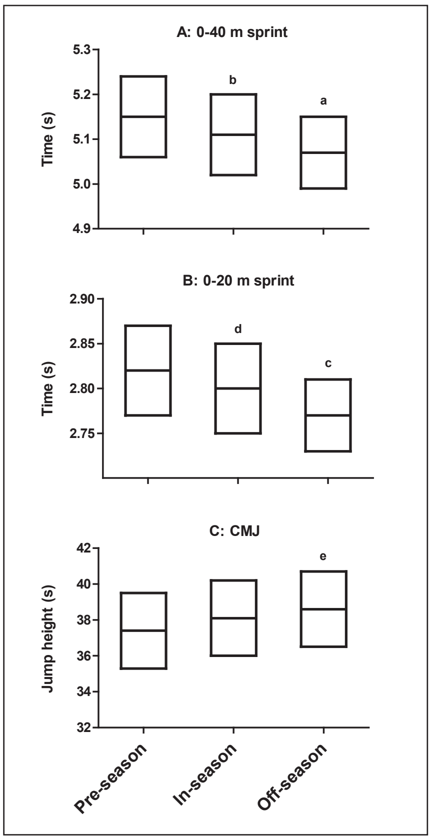

Figure 1. Mean and 90% confidence limits for sprint and countermovement jump (CMJ) performance as a function of time during the soccer season. [a, c] Clearly lower than for in-season and pre-season. [b, d] Clearly lower than for pre-season. [e] Clearly higher than for pre-season.

Figure 2 shows mean and 90% CL for sprint mechanical outputs as a function of time during a soccer season. Substantial differences were observed across the season times for all the analyzed variables. Panel A shows that maximal horizontal power production was likely to most likely greater off-season compared to in-season (mean difference, ±90%CL: 0.5, ±0.4 $W \cdot kg^{-1}$; small) and pre-season (0.8, ±0.4 $W \cdot kg^{-1}$; small). Similarly, maximal horizontal force production was likely greater off-season compared to in-season (0.2, ±0.2 $N \cdot kg^{-1}$; small) (Panel B). Panel C shows that theoretical maximal velocity obtained during pre-season was possibly to very likely lower compared to in-season (0.09, ±0.12 $m \cdot s^{-1}$; small) and off-season (0.14, ±0.09 $m \cdot s^{-1}$; small). Finally, Panel D shows that the force-velocity slope values relative to body mass were possibly to likely higher off-season compared to in-season (0.02, ±0.03; small) and pre-season (0.01, ±0.02; small).

Discussion

To the author's knowledge, no previous studies have quantified seasonal changes in jump and sprinting capabilities in soccer players over the course of one year. This study revealed that male professional players jumped clearly higher off-season compared to pre-season. Superior sprint performance and maximal horizontal power production were observed off-season compared to in-season

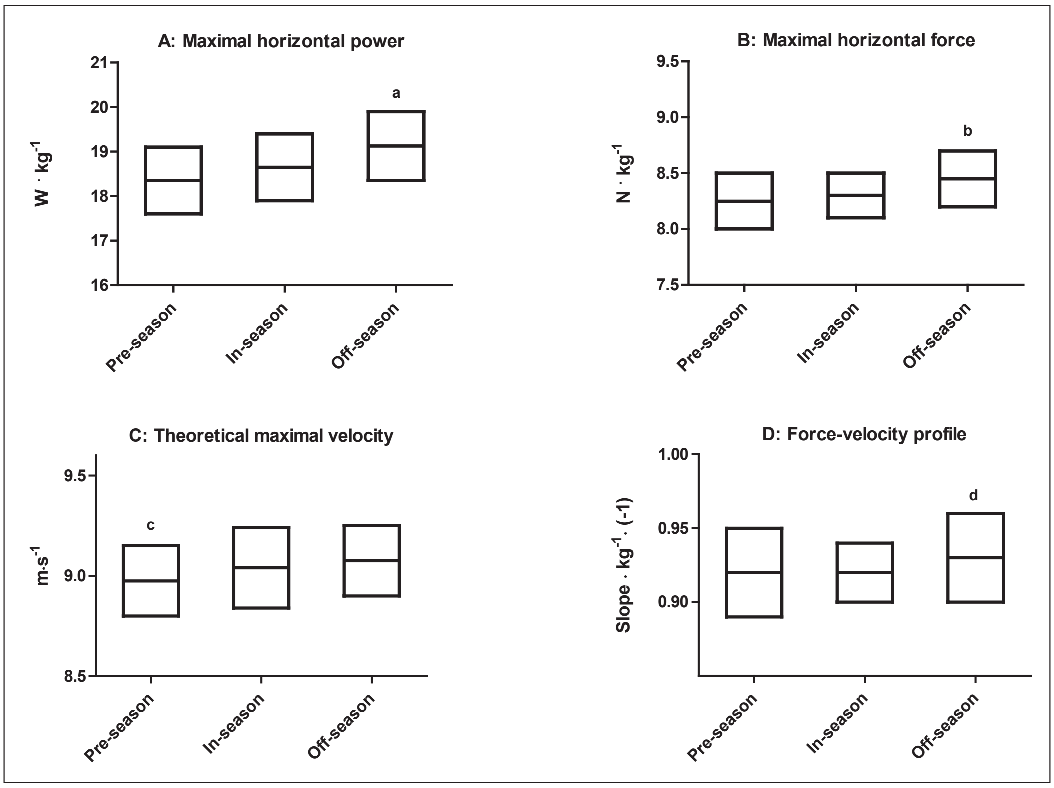

Figure 2. Mean and 90% confidence limits for sprint mechanical outputs as a function of time during the soccer season. [a] Clearly greater than for in-season and pre-season. [b] Clearly greater than for in-season. [c] Clearly lower than for in-season and off-season. [d] Clearly higher than for pre-season and in-season.

and pre-season, and maximal horizontal force production was clearly greater off-season than for in-season. Theoretical maximal velocity was clearly lower pre-season compared to in-season and off-season. Overall, the present results show that anaerobic fitness variables, believed to be relevant for the on-field soccer performance, are sensitive to the varying season times.

When evaluating seasonal performance differences optimally, it is important to consider the actual change in performance (the signal), the noise associated with that particular assessment, and the smallest practical or meaningful change (SWC). According to Hopkins et al. (2009), SWC in team sports can be calculated in two ways: 1) based on empirical observations of direct performance benefits (e.g., a distance of ~30 cm is considered enough to be decisive in one-on-one duels by having body/shoulder in front of the opposing player, corresponding to 0.03-0.04 s over 20-m sprint (Haugen, Tønnessen, Hisdal, & Seiler, 2014; Haugen & Buchheit, 2016), or 2) based on statistical considerations, such as sports-specific standardized changes or differences. For the latter, 0.2 of the between-player standard deviation in team sport players is generally favored to detect small changes (Hopkins, et al., 2009). While the observed differences in CMJ across the season times (~1 cm) are on a par with or lower than SWC and typical variation, the seasonal changes in sprint performance (~0.05 s over 20-m sprint) exceed SWC and typical variation associated with such tests.

The energy demand in soccer is covered by both aerobic and anaerobic processes (Stølen, Chamari, Castagna, & Wisløff (2005). Although anaerobic actions are important within decisive situations, such capabilities are related to immediate constraints of overall soccer conditioning. Indeed, fatigue leads to impaired sprint performance during 90 minutes of match play (Krustrup, et al., 2010; Rampinini, et al., 2011; Nagahara, et al., 2016), and the magnitude of this reduction is positively correlated with a very-high-speed (>25.0 km·h^{-1}) running distance covered during the match (Nagahara, et al., 2016). The results of this study indicate that sprint and vertical jump capabilities are related to constraints over longer terms as well. It is a common practice in soccer that total training load is greatest in pre-season, ahead of in-season and off-season (Jeong, Reilly, Morton, Bae, & Drust, 2011; Malone, et al., 2015). This was also the case for the included players from six Norwegian upper league clubs, based on the author's insights as an employee of the Norwegian Olympic Federation. While increased training load normally leads to enhanced aerobic fitness in soccer players (Silva, et al., 2011; Bradley, et al., 2011, 2014) and vice versa (Gil-Rey, Lezaun, & Los Arcos, 2015), the present results suggest that accumulation of training volume can impair the improvement of anaerobic fitness variables believed to be important for the on-field soccer performance.

The current findings are in accordance with the observations made by Los Arcos, Martínez-Santos, Yanci, Mendiguchia, and Méndez-Villanueva (2015), who reported negative effects of a 9-week pre-season conditioning program on CMJ and sprint performance in male professional players. The same research group reported that accumulated perceived respiratory load was negatively correlated with the changes in 15 m sprint performance in young professional players during a 32-week period (Los Arcos, Martínez-Santos, Yanci, & Mendez-Villanueva, 2017). However, the present results are in contrast to those by Caldwell and Peters (2009) and Requena et al. (2017), who reported no positive off-season effects on sprint and vertical jump performance. The current observations are also contradicting to Fessi et al. (2016), who observed positive pre-season effects on the same variables. The divergence of previous studies with respect to the impact of a season phase may be explained by varying playing standards, training status and conditioning strategies among soccer teams.

The force-velocity slope relative to body mass was clearly higher off-season than for pre-season and in-season for the investigated players (Figure 2, Panel D). Theoretically, the higher force-velocity slope observed off-season could be due to greater horizontal force production capabilities (in the specific context of sprinting push-off), lower maximal sprint velocity, or a combination of these. However, these considerations must be interpreted with caution, as the observed changes in force-velocity slope (~3%) were slightly lower than the noise (CV 4.8%; Table 1) associated with that measure. In general, sprint mechanical outputs are sensitive to timing noise. That is, small timing errors lead to larger, yet acceptable errors in horizontal acceleration data due to the derivation process of the speed-time curve. However, it is reasonable to expect enhanced reliability with increasing timing check points.

In conclusion, this study shows that anaerobic fitness variables, believed to be relevant for the on-field soccer performance, are sensitive to the varying season times. Clearly enhanced sprint and vertical jump performances were observed off-season compared to pre-season and in-season. The present results indicate that such capabilities are related to constraints of overall soccer conditioning. Because the ability to either create or close small gaps can be the difference between winning and losing the game, it is crucial for practitioners to take total training load into account when designing conditioning programs, particularly if the aim is to develop faster players.

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