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Quantifying Training Intensity Distribution in a Group of Norwegian Professional Soccer Players

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Purpose: This study was designed to quantify the daily distribution of training intensity in a group of professional soccer players in Norway based on three different methods of training intensity quantification. ***Methods:*** Fifteen male athletes (age, 24 ± 5 y) performed treadmill test to exhaustion to determine heart rate and VO_2 corresponding to ventilatory thresholds (VT_1, VT_2), maximal oxygen consumption (VO_2max) and maximal heart rate. VT_1 and VT_2 were used to delineate three intensity zones based on heart rate. During a 4 wk period in the preseason (N = 15), and two separate weeks late in the season (N = 11), all endurance and on-ball training sessions (preseason: N = 378, season: N= 78) were quantified using continuous heart rate registration and session rating of perceived exertion (sRPE). Three different methods were used to quantify the intensity distribution: time in zone, session goal and sRPE. ***Results:*** Intensity distributions across all sessions were similar when based on session goal or by sRPE. However, intensity distribution based on heart rate cut-offs from standardized testing was significantly different (time in zone)**.** ***Conclusions:*** Our findings suggest that quantifying training intensity by using heart rate based total time in zone is not valid for describing the effective training intensity in soccer. The results also suggest that the daily training intensity distribution in this representative group of high level Norwegian soccer players is organized after a pattern where about the same numbers of training sessions are performed in low lactate, lactate threshold, and high intensity training zones.

Keywords: soccer, exercise intensity, training zones, training load, perceived exertion

Besides its extreme demands on technique, speed and explosiveness, soccer is arguably the most endurance oriented of the world's most popular team sports. Players cover 8–13 km during a match, with an intermittent exercise pattern.[1–5] Because of the duration and the average intensity of play, the overall energetic profile of soccer is highly aerobic.[1,6]

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Several studies have described both the match activity profiles of top-level soccer players and different training methods for improving physical capacity in soccer. High endurance capacity is important so the players can follow the tactical plan for the game and manage to execute high intensity bursts throughout the entire match.[3,4,7,8]

Exercise intensity and its distribution is probably the most debated issue within endurance training.[9] The day-to-day distribution of training stress should maximize adaptation while minimizing the risk of negative outcomes such as overuse injury, overtraining, or stagnation. Several studies have quantified the daily training intensity on different types of endurance athletes.[10–12] It seems that two basic patterns of training intensity distribution emerge from the research literature. Elite endurance athletes appear to organize their intensity distribution after a polarized pattern, with most sessions performed clearly below (about 75%) and with substantial periods above (15–20%) "lactate threshold intensity."[9,12] In contrast, the threshold training pattern derives its name from the tendency for most training sessions to be performed with intensity at or near the lactate threshold.[12] A lactate threshold centered intensity organization is probably common for untrained subjects and recreational athletes because this is the highest training intensity that can be maintained for an extended period.

No published studies have described the training intensity distribution in high-level soccer players. Whether soccer players organize their training intensity after the same pattern or in a different way than typical endurance athletes is still not known. The primary aim of this study was therefore to quantify the daily training intensity distribution in competitive soccer players, and compare their training characteristics during the preseason with in-season training. A secondary aim was to compare different training intensity quantification methods previously compared in endurance athletes in a team sport setting.

Methods

Subjects

Fifteen male soccer players from a single club competing in the highest division in Norwegian soccer (age, 24 ± 5 y and VO_2max, 58 ± 3 $mL \cdot kg^{-1} \cdot min^{-1}$) were recruited to participate in the study. The study was approved by the internal research ethics committee of the Faculty of Health and Sport, University of Agder. All subjects provided informed written consent before participation.

Preliminary Testing

At the end of the off-season period, all subjects performed a treadmill test to voluntary exhaustion to determine baseline physiological characteristics and training intensity zone cutoffs. The treadmill (Woodway, Wel am Rhein, Germany) was maintained at 3% grade throughout the test. During the test, gas exchange data were collected continuously using an automated breath by breath system (Oxycon Pro, Jaeger BeNeLux, Breda, Netherlands), and were calibrated before each test according to the manufactures instruction. The test was initiated at 7 $km \cdot h^{-1}$. After a 4 min stabilization period, treadmill velocity was increased by 0.75 $km \cdot h^{-1} \cdot min^{-1}$ until voluntary exhaustion. Gas-exchange measurements were used to quantify the first ventilatory threshold (VT_1), the second ventilatory threshold (VT_2), and maximal oxygen consumption (VO_2max). VT_1 was defined as the intensity at which an increase in V_E/VO_2 occurred without an increase in V_E/VCO_2. VT_2 was defined as the intensity at which V_E/VCO_2 also began to rise. VO_2max was defined as the highest average oxygen consumption measured during a 1 min period. Heart rate was continuously registered with 5 s intervals via telemetry (Polar s610, Kempele, Finland) for the determination of heart rates corresponding to VT_1, VT_2 and VO_2max. Two independent observers made ventilatory threshold determinations. In cases of disagreement between the two observers, a third evaluator also quantified the thresholds. Height was determined to the nearest cm. Body mass, body fat and muscle mass were estimated during preliminary testing using octapolar bioimpedance (In Body 720, Biospace Co, Ltd, Seoul, South Korea).

Training Monitoring

All training specific endurance and on-ball training sessions performed during a 4 wk period in the preseason ending 4 wk before the first game of the season (n = 15 players, 378 training bouts), and two separate weeks late in the season (n = 11 players, 78 training bouts) were quantified using continuous heart rate registration and session rating of perceived exertion (sRPE).[26] All strength training sessions in the same periods was also registered as part of weekly training time quantification (preseason: N = 94, season: N = 19). Four players changed club during the summer break of the season, making only 11 of the initial 15 players available for quantifying training intensity in the late season.

Heart rate was monitored for every training session except the strength training sessions by using downloadable, frequency coded heart watches with 5 s registration intervals (Polar Team Pro, Kempele, Finland). All subjects retained a numbered heart rate belt for the entire collection period. Heart rate data files were downloaded to a computer after every training session. Heart rate records were matched against diary contents once a week, to ensure accurate registration. Inactive time (eg, half-time break in a training match) registered on the heart monitor was removed from the heart rate analysis.

Thirty minutes after every training session, the players' rating of perceived effort for the entire session were registered, using the modified 10-point scale developed by Foster and colleagues.[13,14] Athletes were allowed to mark a plus sign alongside the integer value if they wished, which was then interpreted as 0.5 point (for example, 7+ = 7.5 on the 10 point scale).

Training Data Analysis

Three individual heart rate based intensity zones were established based on the results of preliminary treadmill testing. We were not able to perform a second, in-season maximal treadmill test. However, while overall fitness of the athletes is likely to have improved from the preliminary testing time-point, the heart rates associated with physiological thresholds have been shown to be quite stable through a season.[15,16] An intensity $\leq VT_1$ was categorized as zone 1, intensity between VT_1 and VT_2 as zone 2, and intensity $\geq VT_2$ as zone 3. Training intensity distribution was quantified from heart rate using two different methods: "total time in zone" and "session goal" as previously described.[12] Total time in zone was calculated by using VT_1 and VT_2 cut-off heart rates from preliminary testing and analysis of heart rate records from each training session using dedicated heart rate analysis software (Polar ProTrainer 5). The percentage of training time spent in each of the three training zones for each training session was first calculated for each athlete. The average training time in each zone for all athletes was then determined. The session goal method quantified intensity distribution based on nominal allocation of each training session to one of the three intensity zones defined from preliminary testing. Each training session was nominally categorized into the highest intensity zone were the athlete accumulated ≥10 min of training time.

Session RPE data (sRPE, 10 point scale) were divided into three intensity zones: zone 1: ≤ 4; zone 2: above 4 and below 7; zone 3: ≥ 7 based on previous studies (Table 1).[12] Each training session was thus nominally allocated to one of the same three intensity zones described above.

Table 1 Session RPE scale with VT1 and VT2 markers used to delineate three intensity zones

0	—Rest	
1	—Very Easy	
2	—Easy	
3	—Moderate	
4	—Somewhat Hard	
		VT_1
5	—Hard	
6		
		VT_2
7	—Very Hard	
8	—Very, Very Hard	
9	—Nearly Maximal	
10	—Maximal Effort	

Statistical Analysis

Data are presented as means ± standard deviation. Data were analyzed using SPSS (Statistical Package for the Social Science, version 16.0). The means of individual training intensity distributions quantified using two different heart rate methods and session RPE were compared using repeated-measures ANOVA for each intensity zone. A P-value of ≤ 0.05 was considered statistically significant. No direct statistical comparison between preseason and season was made because of different numbers of subjects in the two periods.

Results

The physical characteristics of the subjects and results from the maximal treadmill test are presented in Tables 2 and 3. Injury free, players trained on average 8.3 ± 0.8 training sessions per week (11.1 ± 1.5 $h \cdot wk^{-1}$) during 4 wk in the preseason.

Table 2 Physical characteristics of athletes

N = 15	Mean ± SD
Age	24 ± 5
Height (cm)	181 ± 5
Weight (kg)	77.6 ± 5.4
Muscle mass (kg)	40.4 ± 2.4
Body fat (%)	10.5 ± 2.2

Table 3 Physiological values from preliminary testing

N = 15	Mean ± SD
VO_2max ($L\cdot min^{-1}$)	4.5 ± 0.3
VO_2max ($mL\cdot kg^{-1}\cdot min^{-1}$)	58 ± 3
RER	1.13 ± 0.04
V_E ($L\cdot min^{-1}$)	151 ± 14
HR_{max} (bpm)	189 ± 9
VO_2 at VT_1 ($mL\cdot kg^{-1}\cdot min^{-1}$)	36 ± 5
VO_2 at VT_2 ($mL\cdot kg^{-1}\cdot min^{-1}$)	45 ± 4
VT_1 % of VO_2max	64 ± 5
VT_2 % of VO_2max	79 ± 5
HR at VT_1 (bpm)	147 ± 13
HR at VT_2 (bpm)	164 ± 11
VT_1 % of HR_{max}	78 ± 5
VT_2 % of HR_{max}	87 ± 4

Note. VO_2max: maximal oxygen consumption; RER: respiratory exchange ratio; V_E: pulmonary ventilation at VO_2max; HR_{max}: maximal heart rate; VT_1: first ventilatory threshold; VT_2: second ventilatory threshold.

In-season, the injury free players completed 5.7 ± 1.1 training sessions per week and 7.8 ± 1.3 $h\cdot wk^{-1}$.

Training Intensity Distribution

The calculated intensity distribution includes all training sessions and games in preseason and season (*N* = 456), except strength training sessions (*N* = 113). Data from alternative training sessions (bicycle, ergometer or running) performed by acutely injured players were also included in the training intensity distribution analysis after it was determined that their exclusion did not impact the overall intensity distribution.

Based on the total time in zone heart rate analysis method, 73% of all training time in the preseason was spent at a heart rate below VT_1 intensity, 18% between VT_1 and VT_2, and 9% was above the heart rate corresponding to VT_2. The intensity distribution during in-season training was similar; 71% $\leq VT_1$, 21% between VT_1 and VT_2, and 8% $\geq VT_2$. Training distribution shifted significantly and similarly when the heart rate data was analyzed using the session goal method of heart rate analysis (zone allocation based on the predominant training intensity for the session) or session RPE (Figures 1 and 2). During preseason training, 40% of training sessions were performed $< VT_1$, 34% between VT_1 and VT_2, and 27 $> VT_2$. Similarly, session goal analysis of in-season training identified 35% of the training sessions as $<VT_1$ intensity, 31% between VT_1 and VT_2, and 35% $> VT_2$.

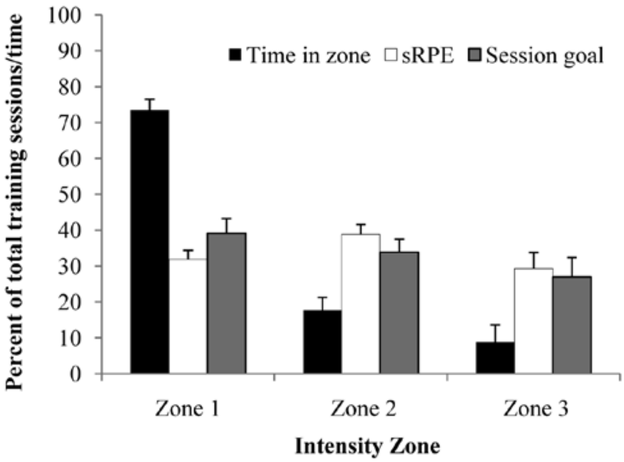

Figure 1 — Intensity distribution in PRE-SEASON based on three different quantification methods. * $P \leq .05$ for time in zone method vs sRPE and Session goal methods.

Based on session RPE data, 35 ± 2% of the total numbers of training sessions in preseason were performed at an intensity of ≤ 4 on the 10 point scale shown in Table 1. 38 ± 2% were performed at an intensity between 4.5 and 6.5, and 27 ± 4% at an intensity ≥ 7. In-season sRPE data identified 37 ± 3% as performed at an intensity ≤ 4, 24 ± 4% between 4.5 and 6.5, and 38 ± 6% were performed at an intensity ≥ 7. A tendency to a right shift in the intensity distribution is seen between preseason and season, with relatively more hard training sessions in-season compared with preseason.

Training Load

The average training load in preseason was 3577 ± 920 arbitrary units (AU) (n = 15 players). Training load varied in this 4 wk period from 4600 ± 668 AU the hardest week, to 2791 ± 588 AU in the last week of the period.

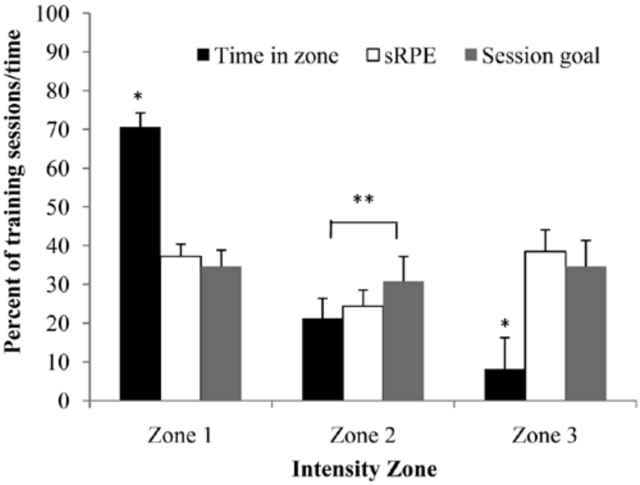

Figure 2 — Intensity distribution IN-SEASON based on three different quantification methods. * $P \leq .05$ for time in zone vs both session goal and session RPE methods. ** $P \leq .05$ for time in zone vs session goal quantification methods.

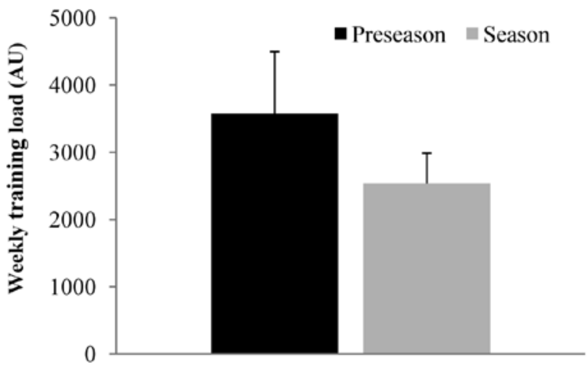

Figure 3 — Weekly training load (sRPE × training time in minutes) based on Foster et al[13] for preseason and in-season training periods. Data from preseason is based on 15 athletes. In-season data is based on 11 of these 15 due to loss of 4 athletes to club trades.

In-season training load in the two separate weeks of quantification was similar. The first week, the training load was 2550 ± 508 AU, and the second week, 2522 ± 428 AU. Average training load in-season was 2536 AU (n = 11 players). Weekly training load for preseason and season training periods are presented in Figure 3.

Discussion

The main findings of our study are that the training intensity distribution in this representative group of high-level Norwegian soccer players is organized after a relatively even distribution among low intensity, lactate threshold intensity, and high intensity training sessions, both in the preseason and season. This intensity distribution is markedly different from what are characteristics of how top-class endurance athletes organize the daily intensity distribution.

The results also suggest that the basic intensity distribution is similar during preseason and in-season training, but with a tendency to more sessions with high intensity in the season. We also find that quantifying training intensity by using total time in zone analysis of heart rate is not a valid method for describing training intensity in soccer.

Total training volume and training load was reduced during the season compared with the preseason build-up. This group of soccer players trained 2–3 more sessions per week and over 3 $hr \cdot wk^{-1}$ more during the preseason. Consequently, average training load was decreased with ~1000 AU in-season compared with preseason. Training load was stable in-season, but varied substantially from week to week during the in preseason with a range from 2791 to 4600 AU. Clearly, the specific periodization of training will be highly influenced by the philosophy of the club trainer. However, it seems reasonable to expect that weekly training load variation decreases once the season schedule begins.

As observed in a similar study of cross country skiers,[12] we found good agreement between the session goal heart rate analysis approach, and perceptual quantification of training using the session RPE method. However, intensity distribution based on heart rate quantification using the total time in zone method was significantly different from the two other methods, both in preseason and season. This method is commonly employed for quantifying training intensity and software is readily available from heart watch manufacturers to facilitate analysis of heart rate records. Our findings suggest that this method gives a misleading picture of the actual training intensity distribution in soccer, and probably in most training types where the intensity is stochastic. This method quantifies the actual time that heart rate recordings are within given defined heart rate ranges during a training session and are therefore quite straightforward. However, a typical training session consists of a warm up phase, a cool down phase, and maybe some short breaks during the primary training session. These training phases are performed with low intensity and pull down the average heart rate for a training session in a manner that does not accurately reflect the nonlinear impact of repeated, brief high intensity work periods on perceived effort for the entire bout.

The session goal method was first suggested by Seiler and Kjerland[12] as an alternative method for quantifying training intensity distribution by integrating heart rate recordings and diary information about each training session. In this study we used a modified version of this method. Each training session was nominally categorized into one of the three intensity zones, defined by treadmill heart rates at VT_1 and VT_2 from preliminary treadmill testing. Heart rate varies throughout a training session. Therefore the nominal categorization was based on the highest intensity zone where the subjects' heart rate was ≥ 10 min. We have previously found that autonomic recovery is delayed when exercise is performed above VT_1.[17] However, relationship between the time spent above a given intensity threshold and autonomic stress is not established. Our choice of 10 min accumulated time was a qualified estimate. For example 4 × 4 min is a typical hard interval work out. In these types of sessions heart rate will exceed VT_2 heart rate for 10–12 min. The present results suggest that the resulting intensity distribution was consistent with the athletes' own perception of effort for the training bouts, based on posttraining evaluation of the exertion demanded by the training session (session RPE).

Measuring exercise intensity in a highly stochastic activity like soccer is a challenge. For endurance athletes, intensity is normally monitored and controlled with heart rate monitoring. This method of intensity measuring in soccer is often criticized because the heart rate monitoring underestimates the physiological stress of repeated short and intensive sprints. It has also been suggested that concentrating on team players and opponents and controlling the ball, or anxiety caused by training or match situations, may lead to heart rates above what reflects the actual work load.[18] However, Hoff et al[19] suggest that heart rate monitoring during soccer specific exercise is a valid indicator of actual exercise intensity. This group of players normally used heart rate monitors on most of their training sessions. Therefore it is unlikely that the process of monitoring heart rate altered their on-field behavior. We combined heart rate monitoring and subjective measures to strengthen the validity.[8,20]

Total training load is an important consideration in any performance optimization setting. In soccer, training sessions are often conducted as a group, which may result in non-optimal intensity loading at the individual level. Endurance training is often described as an external load prescribed by coach (eg, 4 × 4 min at 90% of HR_{max}). However, the true training load on the individual athlete for a given training prescription is a function of the physiological/perceptual stress experienced by the athlete.[21,22] This is important in soccer where the planned external load is often similar for each team member but their responses to the training regime may differ markedly. Using session RPE to calculate training load among athletes has been suggested as a simple, valid and reliable method for quantifying training load in soccer.[21,23–26] In the present study, session RPE was not registered for the strength sessions. Therefore we estimated these sessions by multiply the duration of the sessions by 4.5, a typical session RPE value in different types of strength training sessions.[27–29] This estimation led to an increased total training load by about 15% both in the preseason and the season.

This group of soccer players played in the second highest Norwegian division in the quantification period. They played at the highest Norwegian level both the season before and after, and all were professional players. Average VO_2max values of 58 $mL·kg^{-1}·min^{-1}$ is on the low end of what is characteristic for high level soccer players. The VO_2max measurement was conducted in the start of the preseason and it is likely that these values increased to an in-season level above 60 $mL·kg^{-1}·min^{-1}$ due to a combination of improved absolute capacity and perhaps a small weight reduction. A previous study involving Norwegian soccer players demonstrated that that lower ranked teams in the highest Norwegian level had average VO_2max values about 59 $mL·kg^{-1}·min^{-1}$ in-season.[30] In comparison, the best team in this league has regularly been a participant in the Champions League and has significantly higher VO_2max values (67.6 $mL·kg^{-1}·min^{-1}$).[30] Given the time-point of baseline testing in this study, we are confident that this group of athletes were in the fitness range that is typical of European professional soccer players.

One potential weakness of the study is that we were unable to perform a second in-season maximal treadmill test on the athletes. This was due to concerns by the coaching staff about the stress on the athletes and interference with training and competition. Preliminary testing was performed at the beginning of the preparation period. Therefore, VO_2max values were likely below their in-season fitness level.

However, the heart rate cutoff points used for identification of training zones have been shown to remain stable even as fitness improves during a season.[15,16] We have also observed recently that during a 7 wk high intensity, self-paced interval training program in cyclists, heart rate remained very consistent over 7 wk while interval power output increased (Seiler, unpublished observations). We argue therefore that the interpretation of the intensity distribution data would not have been changed by performing a second in-season test.

Another relevant question involves potential training differences among the players related to their status on the team as starters or reserves. In the preseason, the coach rotated playing time so all players could achieve match training and increase physical fitness. During the season, playing time in league games became much less evenly distributed among the squad. Most of the players included in this study were in the regularly starting squad, and played games once a week. The substitutes played weekly games with the recruit team. There was therefore no practical difference in average weekly training load between starters and reserves.

Ideally we wanted to use a longer training quantification period during the season. This was under the circumstance not possible. However, we believe that both the preseason and in-season quantification periods gave an accurate depiction of how this group of soccer players trained. The daily intensity distribution observed is in clear contrast with how top class endurance athletes distribute their training. Endurance athletes seem to accumulate a large volume of training at low intensity ($\leq VT_1$), combined with 1–3 weekly bouts where significant time is spent at intensities $\geq 90\%$ of VO_2max.[9,12] This "endurance athlete intensity profile" is unlikely to be appropriate for soccer training because it is difficult to accurately simulate soccer play and technique at low intensities. Soccer exercises must be performed at competition intensity for technical transfer to be optimal. A consequence of this is that soccer specific training often is performed as relatively hard workouts. In the present group, soccer specific exercises were rarely performed at low intensity. The exclusively low intensity sessions were mainly in the form of recovery exercise the day after a game and were typically jogging, cycling and swimming, combined with some strength training.

In conclusion, the present results demonstrate that soccer players do not employ a training intensity distribution typical of high-level endurance athlete training more total weekly hours. Instead, their training is marked by most training sessions having significant periods of time at or above the lactate threshold intensity. The unique combination of explosiveness, technique and endurance required to excel in high level soccer challenges coaches to find an optimal training approach to maximize all of these demands. The results of the present study provide information that can be used as a starting point for investigating how training intensity distribution in soccer caries with performance level, and the impact of different training strategies on soccer specific capacity.

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