Rev Bras Cineantropom Hum

original article

DOI: dx.doi.org/10.5007/1980-0037.2019v21e56955

Training intensity distribution of young elite soccer players

Distribuição da intensidade de treinamento em jovens jogadores de futebol

Thiago Oliveira Borges [1]
https://orcid.org/0000-0002-2986-3454
Alexandre Moreira [2]
https://orcid.org/0000-0002-4609-1839
Carlos Rogério Thiengo [3]
https://orcid.org/0000-0002-3343-8979
Rafael Gustavo Silva Duarte Medrado [3]
https://orcid.org/0000-0002-4213-0992
Adriano Titton [3]
https://orcid.org/0000-0001-8330-3776
Marcelo Rodrigues Lima [3]
https://orcid.org/0000-0002-8510-011X
Alexandre Nunes Marins [1]
https://orcid.org/0000-0002-3950-5319
Marcelo Saldanha Aoki [1]
https://orcid.org/0000-0001-7803-6829

Abstract – The current study described the training load and intensity distribution of 30 elite Under 20 soccer players (17.9 ± 0.6 years, 180.3 ± 5.7 cm, 73.7 ± 8.8kg) from a 3-time FIFA Club World Cup champion. Session-rating of perceived exertion (s-RPE), internal training load (ITL) and monotony were recorded across 40 training sessions. Mixed-effects modeling was used for data analysis. The athletes performed 33.0 ± 6.9 out of 40 planned training sessions. Most common reasons for absence from training included sickness or minor injuries. Overall, these training sessions summed 2928.7 ± 627.6 minutes. Athletes performed significantly more training sessions at low and moderate intensity zones than at high-intensity zone (p <0.0001). The current data indicate that elite young soccer players perform their training sessions predominantly at the low-intensity zone. Training monitoring is an important aspect of the sport training process evolution. In fact, previous evidence has already shown that an appropriate intensity distribution prevents maladaptation from sports training and may optimize athletic performance. Therefore, coaches should implement strategies to monitor training loads during pre-season and competitive periods.

Key words: Soccer, Intensity Distribution, Training Loads, Mixed Modelling

Resumo – *O presente estudo descreveu a carga de treinamento e a distribuição de intensidade de 30 jogadores de elite de futebol sub 20 (17,9 ± 0,6 anos, 180,3 ± 5,7 cm, 73,7 ± 8,8 kg) de um clube de elite do estado de São Paulo. Durante 40 sessões de treinamento, a percepção subjetiva de esforço, bem como a carga interna de treinamento e a monotonia foram registradas. Os dados foram analisados por modelagem linear mista. Os atletas realizaram 33,0 ± 6,9 das 40 sessões de treinamento planejadas. As razões mais comuns para a ausência nas sessões de treinamento incluíram doenças ou lesões leves. De forma geral, essas sessões somaram 2928,7 ± 627,6 minutos. Os atletas realizaram significativamente mais sessões de treinamento em zonas de baixa e moderada intensidade comparado com a zona de alta intensidade (p <0,0001). Os dados do presente estudo indicam que os jovens jogadores de elite realizam suas sessões de treinamento predominantemente na zona de baixa intensidade. O monitoramento do treinamento colabora para a evolução do processo de treinamento esportivo. De fato, evidências anteriores já mostraram que a distribuição de intensidade apropriada impede a mal adaptação ao treinamento esportivo e pode otimizar o desempenho atlético. Portanto, treinadores devem implementar estratégias para monitorar as cargas de treinamento durante os períodos de pré-temporada e de competição.*

Palavras-chave: *Futebol; Distribuição da intensidade; Carga de treinamento; Modelagem mista.*

1 University of São Paulo. School of Arts, Science and Humanities. São Paulo, SP. Brazil

2 University of São Paulo. School of Physical Education and Sport. São Paulo, SP. Brazil

3 São Paulo Football Club. Athlete Development Center President Laudo Natel. Cotia, SP. Brazil

Received: 10 May 2018
Accepted: 13 December 2018

How to cite this article
Borges TO, Moreira A, Thiengo CR, Medrado RGSD, Titton A, Lima MR, Marins AN, Aoki MS. Training intensity distribution of young elite soccer players. Rev Bras Cineantropom Desempenho Hum 2019, 21:e56955. DOI: http://dx.doi.org/10.5007/1980-0037.2019v21e56955

INTRODUCTION

Periodization is a strategy to manipulate training loads (TL) to ensure an appropriate balance between training stress and recovery. Consequently, the adaptive response and gains in athletes' performance are optimized, whilst avoiding the adverse outcomes of undesirable cumulative stress[1-3]. One essential aspect of periodization is the distribution of training intensity. The interest regarding the training intensity distribution has received substantial attention from sports scientists, particularly, in the last decade[4-6]. For example, Seiler et al.[6] have proposed the use of 3 intensity zones, which are mainly determined based on the ventilatory thresholds. The proposed training intensity zones were therefore divided into zone 1 (Z1) (low intensity – below the aerobic threshold), zone 2 (Z2) (intermediate zone – between the aerobic and the respiratory compensation threshold) and zone 3 (Z3) (high-intensity zone – above the respiratory compensation threshold).

Adopting the proposed intensity zones division, Seiler et al.[6] reported that young (17-18 years) cross-country skiers rated ~76, 6 and 18% of their session-ratings of perceived exertion (s-RPE) in Z1, Z2 and Z3, respectively, over 32 consecutive days of training. This pattern was also observed for rowers[7,8], adult cross-country skiers[9], and runners[10], indicating that endurance athletes tend to present a polarized training intensity distribution with training sessions occurring mostly in the low-intensity zone, followed by high-intensity zone, and with less work done at the intermediate zone.

Endurance athletes clearly present a polarized training intensity distribution. In contrast, team sports athletes have shown a different intensity distribution profile[4,11,12]. For instance, Algrøy et al.[11] quantified the daily training intensity distribution in a group of 15 male Norwegian professional soccer players based on 3 different methods of training quantification (time in zone, session goals, and session RPE). The results of this study indicated that the training intensity of professional soccer players presents an even distribution between the low, moderate and high-intensity zones. In addition, these findings suggest that session-RPE is an appropriate and useful method to quantify and assess training intensity distribution.

Using the session-RPE method to delimit intensity zones, Moreira et al.[4] demonstrated that professional Australian football players trained mostly at moderate or high-intensity zones. Additionally, Lovell et al.[12] reported similar intensity distribution based on session-RPE cut-off points, for Rugby League players. These findings also provide evidence that session-RPE is a valuable global indicator of training load and intensity for team sports athletes.

The data from the studies above suggest a distinct training intensity distribution pattern for team sport and endurance adult athletes. However, it is paramount to highlight that the training intensity distribution of young team sports athletes suggest distinctly different training intensity distribution patterns and has yet to be investigated. This is particularly important as young athletes perform intensive training schedules[13] and elite young soccer players frequently compete in matches separated by short time intervals on the top of their usual training routines[14]. Nevertheless, little is known regarding how these young soccer players distribute their training intensity, particularly during a preparation period that precedes important competitions. Therefore, this study aimed to describe the training intensity distribution and the training load of elite young soccer players during a preparatory period for the major competition of the year, using the session-RPE method to determine cut-off points. It was hypothesized that young athletes spend most of their training at lower intensity zones, due to the characteristics of this particular training period of the study.

METHOD

Participants

Thirty young elite Under 20 soccer players (17.9 ± 0.6 yr, 180.3 ± 5.7 cm, 73.7 ± 8.8 kg) from an elite soccer club from São Paulo participated in the study. After ethics approval by the local University Research Ethics Committee (School of Physical Education and Sport, University of São Paulo, 07/2012), the experimental protocols were explained in detail to the participants and their parents. Written informed consent was obtained from each participant and their respective parents or guardians.

Experimental design

The study was conducted during a 5-week training period that preceded the start of the main soccer championship for this age group. The study started after a full week of recovery. The athletes spent the 5 weeks of the study in a controlled environment (team's training centre). Training characteristics are thoroughly described in Table 1. The session-ratings of perceived exertion (s-RPE) of 40 sessions were recorded, according to a method previously described[15]. The s-RPE method describes the internal training load that the athletes experiment when performing the actual training activities and is considered as a global rating of training stress[13,16]. The method allows for calculation of indices that include the internal training load (ITL), determined as the product of the s-RPE and session duration (in minutes), training monotony represents the ratio between the average weekly ITL and the weekly ITL standard deviation. Total ITL was the sum of the week ITL. The training sessions were divided into training zones according to the Borg CR-10 RPE scale[17]. The cut-off points were as follows: low, ≤4 AU; moderate, above 4 and below 7; and high ≥7, according to zones adopted by others[4,6,12].

The volume of the different training content is described on table 1. Physical tests sessions were intermittent beep test. These were performed to determine the maximal aerobic speed of the players. Core and strength sessions aimed to develop the strength of the main core muscles and general strength development, including squats, leg-press, trunk and arms.

Recovery sessions were performed as soft tissue manipulation and stretching. Technique and tactics and speed, technique training sessions were all performed in the pitch, with the ball, in order to develop specific soccer skills, as well as the physical fitness of the players. All the training sessions were routine to the team, and the researchers had no input on that part.

Statistical analyses

Data are presented as mean ± SD unless stated otherwise. Data were log-transformed to reduce non-uniformity of error when they violated the assumption of normality. A mixed-effects model was used to determine the individual responses of the dependent variables collected from the athletes. The model used the participants as random effect whereas the fixed effects were session number, weeks of training and number of sessions and time spent within training zone. The *t* and chi-square statistics from the linear mixed modeling were converted into r-values and interpreted as the effect size (ES)[18]. The interpretation of ES was based on thresholds of 0.0, 0.1, 0.3, 0.5, 0.7, 0.9 and 1 as *trivial*, *small*, *moderate*, *large*, *very large*, *nearly perfect* and *perfect*, respectively. Confidence intervals (90%) were calculated for the estimates generated by the model. Pair wise t-test with Bonferroni correction was used as post hoc procedure for the number of sessions and time spent in intensity zone. All statistical procedures were performed using the R software and the multilevel package for R. Level of significance adopted was p<0.05.

Table 1. Mean ±SD of the time spent (minutes) in each of the training types by week.

	Physical Tests	Core and strength	Recovery	Technique and tactics	Speed + Technique	Match (Friendly or Official)
Week 1	92.0 ± 0.0	67.4 ± 28.0	30.0 ± 0.0	98.5 ± 28.3	100.0 ± 0.0	-
Week 2	-	68.5 ± 24.0	-	98.0 ± 23.7	115.0 ± 23.9	80.0 ± 0.0
Week 3	-	105.0 ± 0.0	30.0 ± 0.0	107.0 ± 0.0	87.0 ± 0.0	111.7 ± 34.6
Week 4	-	50.0 ± 0.0	-	105.0 ± 0.0	116.0 ± 29.1	87.5 ± 29.9
Week 5	-	-	56.0 ± 0.0	73.3 ± 19.4	-	103.2 ± 19.6

Note. Obs: Speed + Technique and tactics sessions involved performing similar work as Technique and tactics, but aiming to develop these qualities at higher speeds.

RESULTS

Training intensity distribution (by training zone)

The athletes performed 33.0 ± 6.9 out of 40 planned training sessions. Most common reasons for absence from training included sickness or minor injuries. Overall, these sessions summed 2928.7 ± 627.6 minutes of training. Athletes performed significantly more training sessions at low and moderate intensity zones than at high intensity zone (p <0.0001) (Figure 1). Similarly, the time spent in zone was also greater for Z1 and Z2 intensity zones, compared to the (Z3)(p <0.0001). The number of training sessions performed within each training intensity zone showed a significant linear trend over time - coefficient of estimate: -1.22 (90% CI -1.38 to -1.04) - t(59) = -12.2, p<0.0001, ES = 0.85 *very large*. The data presented a significantly intra-individual variation between training zones, as well as number of sessions performed in Z1 - $\chi^2(6)$ = 13.3, p=0.0013, ES = 0.36 *moderate*, $SD_{intercept}$ = 0.09 (90% CI 0.01 to 0.63), SD_{slope} = 0.40 (90% CI 0.26 to 0.59). The time spent in each training zone also presented a significant linear trend – coefficient of estimate -1.79 (90% CI -2.34 to -1.24), t(41) = -5.48, p < 0.001, ES = 0.65 *large*. The time spent in each training zone presented a significant intra-individual variation as well as time spent in Z1 - $\chi^2(6)$ = 17.7, p=0.0004, ES = 0.46 *moderate*, $SD_{intercept}$ = 0.34 (90% CI 0.09 to 1.22), SD_{slope} = 1.23 (90% CI 0.84 to 1.80).

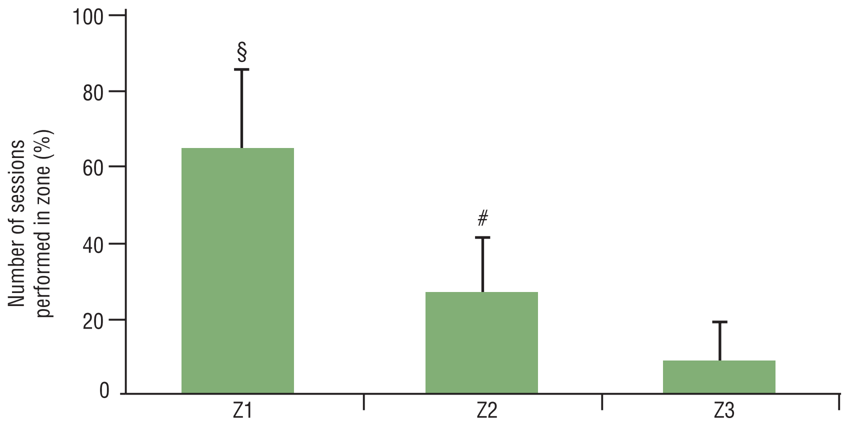

Figure 1. Percentage of the number of training sessions performed in each training intensity zone. § - Significantly higher than Z2 and Z3 – p < 0.01; # - Significantly higher than Z3 – p < 0.01. Z1 – training zone 1: Intensity below rating ≤ 4 AU; Z2 – training zone 2: Intensity above 4 and below 7 AU; Z3 – training zone 3: training intensity > 7 AU. All zones correspond to Borg's CR-10 rating of perceived exertion scale.

Internal Training Load (ITL) over time (by session)

The session ITL showed a significant non-linear (quadratic) trend over time – t(958) = -2.0, p=0.04, ES = 0.06 *trivial*. The data presented a significantly better adjustment in the quadratic model, compared to the linear model - $\chi^2(1)$ = 4.1, p=0.04, ES = 0.06 *trivial*. The random part of the model showed a significant variation of the training loads for the athletes $\chi^2(3)$ = 47.7, p<0.0001, ES = 0.2 *small*, $SD_{intercept}$ = 0.13 (90% CI 0.11 to 0.19), SD_{slope} = 0.0001 (90% CI 0.0000 to 43.0341).

Weekly ITL over time (by week) and monotony

The weekly ITL showed a significant non-linear (quadratic) trend over time – t(1086) = -12.6, p<0.0001, ES = 0.35 *moderate* (Figure 3).Players presented a significant individual response variation (slope) for weekly ITL over time - $\chi^2(1)$ = 63.3, p<0.0001, ES = 0.24 *small*.

Monotony showed a non-significant variation over time, with 1.9 ± 0.5, 2.6 ± 0.6, 1.7 ± 0.3, 2.2 ± 0.6, and 1.9 ± 0.8 A.U. from week 1 to 5, respectively (Figure 3). However, the between athlete variation was significant - $\chi^2(6)$ = 218.8, p<0.0001, ES = 0.40 *moderate*, $SD_{intercept}$ = 0.45 (90% CI 0.33 to 0.61), SD_{slope} = 0.13 (90% CI 0.09 to 0.16).

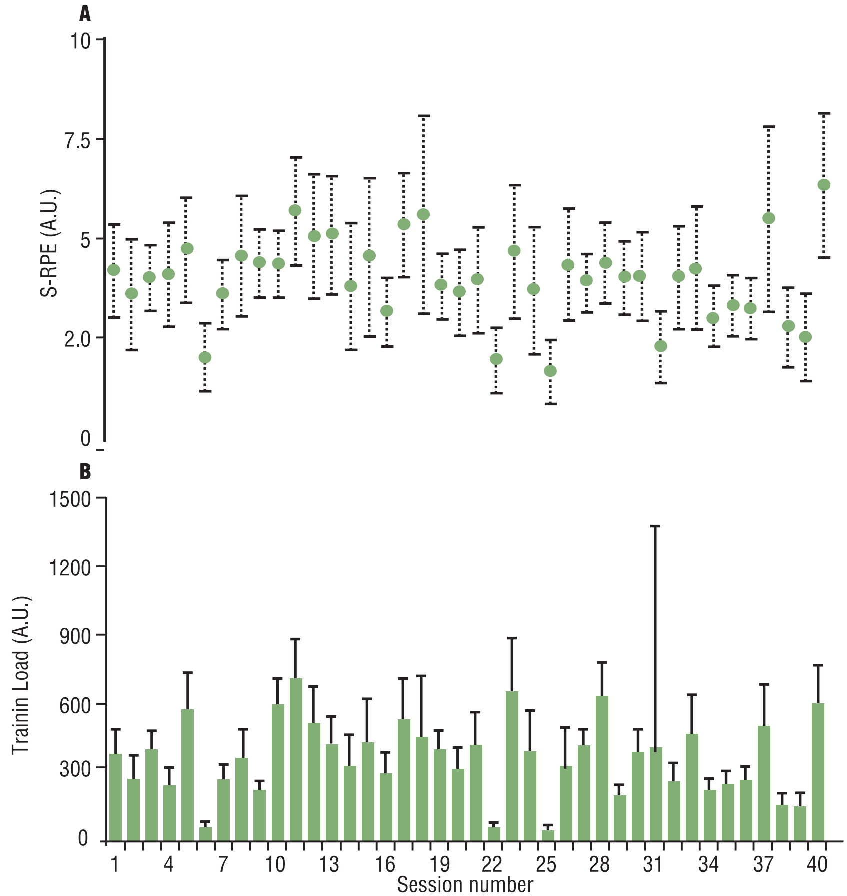

Figure 2. Mean ± SD of the session rating of perceived exertion (s-RPE) (black-filled dots, SD as dashed lines – panel A) and ITL (columns, SD as black lines - panel B) over the 40 training sessions performed by the athletes.

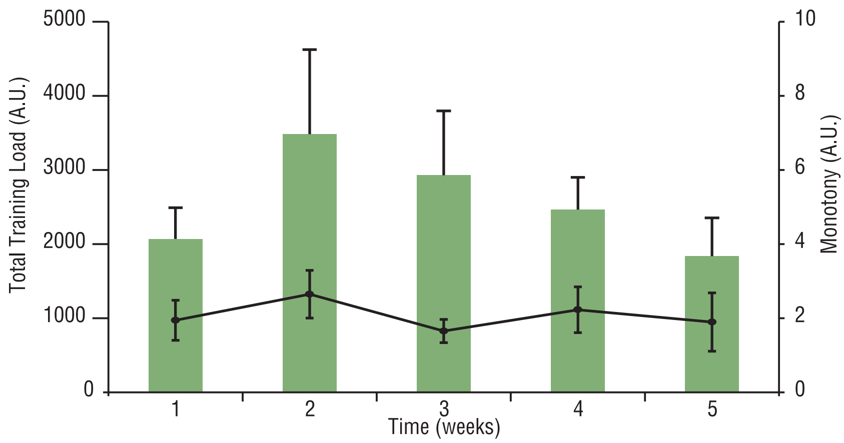

Figure 3. Mean ± SD of weekly ITL (columns, left y-axis), monotony (solid line, right y-axis) over the 5 weeks of training. AU. – Arbitrary units; W – week number.

DISCUSSION

This study described the training intensity distribution and the ITL of young elite soccer players during a 5-week training period preceding an official competition. The main findings of this study were that the players trained mostly at the low-intensity zone, followed by the intermediate and high-intensity training zones. Moreover, the ITL presented a significant quadratic response over time. In addition, player's response to training was significantly heterogeneous. Additionally, the weekly ITL showed a significant quadratic trend. Finally, despite a non-significant variation over time, training monotony presented a significant variation between players. These findings are novel and may aid coaches and researchers to understand how elite young soccer players train, particularly during a period preceding the major competition of the year. To the best of the authors' knowledge, this is the first study to describe the training intensity distribution and the ITL response of elite young soccer players during a pre-competitive mesocycle (5 weeks of training). Despite previous investigations have investigated these variables in adult team sports players[4,11,12], little information about the distribution pattern of elite young soccer players is available.

Interestingly, the ~17 years old players in the present study performed approximately 70 % of their training sessions as low-intensity (Z1 whereas the intensity in Z2 and Z3 represented ~25 and 15% of total training, respectively. Likewise, Castagna et al.[19] reported a 73, 19, 8% intensity distribution for Z1, Z2,and Z3, respectively in adult soccer players (25 ±4 years). Nonetheless, it is important to highlight that Castagna et al.[19] used a heart rate-based method to quantify the training intensity distribution. Different monitoring methods provide distinct information on the stress imposed on individuals. Therefore, caution is needed for analyzing and comparing these investigations. On the other hand, Algrøy et al.[11] reported that elite Norwegian soccer players (24 ± 5 years) displayed a balanced training intensity distribution. The values of 35, 38 and 27% were found during pre-season, and 37, 24 and 38% for the in-season for Z1, Z2 and Z3, respectively. These contrasting results may reflect training experience and training culture since each investigation was conducted in different countries. Moreover, this study assessed a real, non-simulated scenario, which also may help to explain this particular distribution. Since all training sessions were computed for analysis, recovery sessions, as well as training sessions with several pauses may have inflated the training completed at low (Z1) intensity zone.

A more even training intensity distribution was also found in Australian Football players (AF)[4]. The results of this study suggested that AF players (22.9 ±3.0 years) distributed the training intensity similar to the soccer players investigated by Algrøy et al.[11]. However, Moreira et al.[12] found a higher percentage of training sessions performed at the moderate intensity. It appears that AF players undertake a great number of training sessions at moderate and high-intensity compared with soccer players. In addition, marginally differences were also demonstrated between pre-season and in-season. The authors reported that ~27, 55 and 18% of the training sessions were performed in low, moderate, and high-intensity zones, during pre-season, compared to in-season and values of 27, 50 and 23%, respectively, were shown for the in-season phase, suggesting a greater number of sessions performed at high-intensity during the in-season.

The session-RPE is a simple method to assess and quantify training load and training intensity in team sports athletes. Also, it has been considered as a better method to be used in these types of sports, compared to the HR-based methods[12,19]. In addition, Lovell et al.[12] proposed that different methods for monitoring training provide different information on the actual stimulus applied to players during training sessions. For instance, skills sessions present higher HR zones whereas performing wrestling activities session-RPE may be higher. Taken together, it seems that the method for quantifying training play an important role to provide accurate information to coaches and sports scientists.

Moreover, as a novel finding of the present study, it could be inferred that professional team sports players perform more centralized, higher intensity training, whilst younger soccer players accomplish more training sessions at the low-intensity zone. It could be speculated that youth athletes might benefit from using such distribution focused on the low-intensity zone, as they still need to develop their general fitness, to build the “base” for more intensive and sport-specific training, while avoiding symptoms of non-functional overreaching, or even reducing the risk for burnout and dropout.

Training periodization requires that ITL vary to allow optimized training-induced adaptations[20,21]. Therefore, the quadratic trend in the ITL was expected since week 1 was a lighter week, followed by a larger increment in the following weeks (week 2 and week 3) (Figure 3). The elevation in the weekly ITL was due to an increase in training volume (Figure 3). In fact, the total ITL was expected to rise, along with training volume increment[22]. In addition, the ITL response of these players was significantly heterogeneous. This result was rather surprising since all the athletes spend most of their time in the same environment, sharing accommodations, food and undertaken similar training stimulus. Nevertheless, this finding corroborates others with both young and adult athletes suggesting that individuals performing the same external TL may present distinct ITL response[19,23]. As total ITL derives from the individual ITL, it was expected that these 2 variables present related outcomes. Indeed, total ITL also showed a significant quadratic trend with smaller ITL in week 1, followed by an increment from the week 2 onwards (Figure 3). Collectively, these results support even further the individualization of the TL to increase the training-induced response, as well as highlight the importance of monitoring the dose-response relationship in order to optimize training.

Training monotony represents the variation of the ITL over a specific period[24]. The training-induced adaptation relies on few aspects including the stress:recovery ratio[23,24]. Therefore, a proper training design should take into account not only the amount of training but also an appropriate balance between training and rest. Coaches deliberately organize their training loads to maintain the monotony level low, particularly leading into the competition in order to avoid maladaptive outcomes[24]. The current findings corroborate this premise since the period of this study corresponded to the last 5 weeks leading into the main competition of the year for those athletes. Similarly, Suzuki et al.[25] showed that a training program of a Japanese sprinter revealed a low monotony index when the primary competition was close. As a result, training presented an increased degree of variation and reduced stress from training. Moreover, Foster[24] and Suzuki et al.[26] presented evidence that enhanced performance relates to a low degree of monotony. Even though these studies were conducted in different sports with distinct demands, it appears that training variation is key to maintaining positive adaptations through the training cycle.

Players from the present study displayed significant between-subject variation for the monotony index, suggesting that players performing a similar training program not only present individualized ITL response but also show individualized training variation. Possible explanations may relate to fitness level and/or the different physical demands of each playing position[27]. Taken collectively, these findings support the training individualization as an important aspect of training programming in young elite soccer players.

This study was conducted with soccer players that represent the highest level of athletes for this age group. This may limit the generalization and the application of this data may be done taking these particular characteristics into account. However, coaches and sport scientists could use these findings as a reference to guide the preparation of other developing athletes.

CONCLUSION

Elite young soccer players from the same club perform their training sessions predominantly in the low-intensity zone. In addition, these players present significant inter-subject variability in the ITL responses and monotony over time.

Acknowledgments
The authors would like to thank all the athletes and staff at the Athlete Development Center - President Laudo Natel – São Paulo Football Club - for their support and commitment to the study.

COMPLIANCE WITH ETHICAL STANDARDS

Funding
The authors also would like to thank funding provided by FAPESP [Grant: 2012/20309-3].

Ethical approval
Ethical approval was obtained from the local Human Research Ethics Committee – School of Physical Education and Sport, University of São Paulo, protocol (no. 07/2012) was written in accordance with the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed the experiments: TOB, AM, MSA. Performed the experiments: TOB, CRT, RGSDM, AT, MRL, ANM. Analyzed the data: TOB. Contributed reagents/materials/analysis tools: CRT, RGSDM, AT, MRL, ANM. Wrote the paper: TOB, AM, MSA.

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Corresponding author
Marcelo Saldanha Aoki
University of São Paulo - School of Arts,
Sciences and Humanities
Av Arlindo Bettio, 1000. Zip code: 03828-000.
São Paulo – SP – Brazil
Email: aoki.ms@usp.br