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TRAINING STRATEGIES TO MAXIMISE RECOVERY AND PERFORMANCE IN SOCCER PLAYERS

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PROLOGUE

Sports science is a discipline that has been incorporated to a greater extent in the sporting environment, with the aim of improving performance. Sport science is not a perfect science, but the application of scientific principles to sport may help to improve performance. Through the study of sport science, researchers have developed a greater understanding of how sporting exercises can affect physical and physiological adaptations. Training principles were systematic summaries of scientific findings and defined as rules and methods that can be used to prepare athletes and teams for competition. This ever-increase pursuit for the best results, as well as the interest for a scientific approach, were part of the rationale behind my Ph.D. course in sports science. For this reason, in agreement with my supervisors, I planned my studies and researches in order to provide reliable applications in the field-based context helping players and coaches involved in soccer.

The main topic of my Ph.D. project is focused on training methods and strategies to maximize recovery and performance. In particular, I studied the effect of tapering strategies on physical preparedness, comparing the effects of different sprint durations on soccer-physical adaptation. This would contribute to plan and develop soccer training programs aimed to enhance physical performance.

The present thesis was conducted at the Department of Biomedical Sciences for Health of the University of Milan, during 2015-2017 and the Institute for Health and Sport of the Victoria University, Melbourne, Victoria, Australia, during the period 2017-2018.

PUBLICATIONS

Scientific publications I have published in my three years of the Ph.D. course are listed below:

1. F.M. Iaia, M. Fiorenza, **E. Perri**, G. Alberti, G.P. Millet, J. Bangsbo. The effect of two-speed endurance training regimes on performance of soccer players. Plos One. (DOI: 10.1371/journal.pone.0138096) 2015.
2. A. Trecroci, S. Longo, **E. Perri,** F.M. Iaia, G. Alberti. Field-based physical performance of elite and sub-elite middle-adolescent soccer players. Research in Sports Medicine (DOI:10.1080/15438627.2018.1504217). 2018
3. Trecroci A, Cavaggioni L, Lastella M, Broggi M, **Perri E,** Iaia FM, Alberti G. Effects of traditional balance and slackline training on physical performance and perceived enjoyment in young soccer players. Research in Sports Medicine (DOI:10.1080/15438627.2018.1492392). 2018

Scientific publications under review are listed below:

1. **Perri E**., Bishop D. J, Zanasi F., Savino M., Alberti G. & Iaia FM. The effect of sprint duration during sprint-endurance training on changes in soccer-related physical performance in men. International Journal of Sports Physiology and Performance. (UNDER REVIEW)

2. **Perri E**., Trecroci A., Pellegrini E., Alberti G., Bishop. D. J., Iaia FM. Reduction in training load 24 h before a match improves physical performance in soccer players. International Journal of Sports Physiology and Performance. (UNDER REVIEW)

3. Trecroci A. Porcelli S., **Perri E**., Pedrali M., Rasica L., Alberti G., Longo S., Iaia FM. Effects of different training interventions on the recovery of physical and neuromuscular performance after a soccer match. Journal of Strength and Conditioning Research (UNDER REVIEW)

4. Andrade-Souza V. A., Bishop D.J., Ghiarone T., Sansonio A., Silva K., Tomazini F., Arcoverde L., Granata C., **Perri E**., Fyfe, J., Kuang, J., Saner, N., Bertuzzi R., and. Lima-Silva A. E. (2018). Exercise twice on the same day, not only the reduced skeletal muscle glycogen content, improve the transcription of genes involved in skeletal muscle mitochondrial biogenesis. Nature Communications. (IN PREPARATION)

5. **Perri E.,** Bishop D. J., Pellegrini E., Alberti G. & Iaia FM. The acute effect of speed endurance vs. repeats sprint training on moderately-trained soccer players. International Journal of Sports Physiology and Performance. (IN PREPARATION)

6. Rossi A, **Perri E**, Pappalardo L, Cintia P, Iaia F M. Relationship between external and internal workloads in elite soccer players: comparison between Rate of Perceived Exertion and Training Load. (IN PREPARATION)

Scientific publications presented at congresses are listed below:

1. Rossi A., **Perri E**., Trecroci A., Savino M., Alberti G., Iaia F.M. Characterization of in-season elite football training by GPS features – The identity card of a short-term football training cycle. Paper accepted at ICDM Barcelona 2016.
2. **E. Perri**, A. Trecroci, F.M. Iaia, G. Alberti. Physiological and mechanical assessment of an intermittent sub-maximal field-based test in young soccer players. Sports Sciences for Health - ISSN:1824-7490 vol. 12 (Suppl. 1) 2016
3. **Perri E.**, Iaia F.M, Alberti G. The effect of two different training approaches on physical performance in young soccer players. pp.1-2. Football medicine strategies return to play - ISBN:9788860284662. 2016

4. **Perri E.,** Massari M., Iaia F.M., Alberti G. Analysis of performance in different agility tests in young soccer players. pp.393-393. ECSS In: Book of abstract - ISBN:9783000533839. 2016

5. Rossi A., **Perri E.**, Trecroci A., Formenti D., Cavaggioni L., Iaia F.M., Alberti G. GPS features reflect the players' rate of perceived exertion of a football match. In: The Future of Football Medicine - ISBN:9788860285058. 2017

6. A. Trecroci, L. Cavaggioni, **E. Perri**, A. Rossi, D. Formenti, M. Iaia, G. Alberti. The relationship between change of direction ability and dynamic balance in young soccer players. In: The Future of Football Medicine, XXVI International Conference on Sports Rehabilitation and Traumatology. 2017

7. **Perri E.,** Apone M., Alberti g., Iaia FM. Relationship between intermittent sub-maximal field-based test and yo-yo ir1 in recreational soccer players. In: European college of sport science. 2017

8. Rossi A., **Perri E.**, Trecroci A., Savino M., Alberti G., Iaia F.M. GPS data reflect players' internal load in soccer. In: 2017 IEEE 17th International Conference on Data Mining Workshops (ICDMW).

9. Duca M., **Perri E**., Rossi A., Trecroci A., Iaia F.M., Alberti G. Use of questionnaire for monitoring soccer players' recovery and its impact on injury risk. pp.362-362. In: Football medicine outcome: abstract book - ISBN:9788860285416. 2018

10. Trecroci A., Cavaggioni L., **Perri E.,** Duca M., Iaia F.M, Alberti G. The relationship between athletic movement competency and change of direction ability in young sub-elite

soccer players. pp.407-408. In: Football Medicine Outcome: Abstract book - ISBN:9788860285416. 2018

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ABSTRACT

Introduction: In soccer, the long duration of the competitive season and the large number of games require a careful organization of the training load and a maximization of the training stimuli. The presence of close matches (from 7 to 3 days) requires a careful control of accumulated fatigue and the use of training stimuli aimed at improving different aspects of the soccer physical performance. However, to date in soccer, there is little information about the characteristics of tapering during the microcycle, while the knowledge concerning the specificity of the training methods remains confused.

Purpose: the aims of the present investigation were threefold: i) to examine the effect of in-week tapering strategy (reduction in training load 24 h before a match) on player preparedness; ii) to compare the physiological response and mechanical profile of different training strategies, and iii) to compare their effects on soccer-related physical performance.

Methods: For these training studies three soccer teams were involved, with a total of 41 players. In the first study, a cross-over experimental design was used, and the participants performed two simulated match-week microcycles, with the same workload, except for the experimental week where a further reduction of ~33% of the volume (time) was performed the day before the match. In the second study was used a parallel two-group, work-matched, longitudinal (Baseline-Test Post-test) experimental design. Two different speed endurance training protocols were compared before and after four weeks of training. In the third study, the acute physical and physiological response of two training approaches (speed endurance vs. repeat sprint training) were compared.

Results: In the first study, it was found that a further 33% of training-load reduction the eve of the match improved the height of a countermovement jump, sprint time over a 20 m and repeated sprint ability, enhancing preparedness, while Yo-Yo IR1 performance was maintained. The second study showed that 10-seconds sprint was associated with a *possibly* greater effect on repeat-sprint total time, higher power output, as well as lower blood lactate concentration, compared to 20-seconds sprint. In the third study, we showed that repeated sprint exercise is associated with a higher mechanical load and heart rate response, while speed endurance training is associated with a higher speed average and a higher blood lactate concentration at the end of the exercise.

C**onclusion**: A further volume reduction during tapering provides an improvement of jump and sprint performances. Additionally, the assessment of the sprint duration (during repeated sprint) has shown that short-time sprint generates higher power demand and higher mechanical load. Conversely, long-sprint duration generates higher speed and high level of blood lactate concentration. However, both short and long-sprint duration have a positive effect on soccer-related performances. Therefore, the manipulation of the training load during tapering together with the type of training stimulus led to increasing soccer-physical performance.

Keywords –*; Tapering; training loads; GPS; speed endurance training; repeated sprint exercise; soccer.*

1° CHAPTER – Introduction

Soccer is considered the most practiced and popular sport in the world and is played by men, women, and children throughout every continent [1]. The “beautiful game” as many calls it is a multi-million-dollar industry with broad public and commercial interest that continue to evolve. As a result of this constant evolution, science has been incorporated to a greater extent on soccer with the purpose of enhancing performance. Thus, over the last decades, several researches have focused on soccer and its particular issues, including performance determinants, players’ physical characteristics and specific training-induced effects [1-6]. However, despite this ever-increase amount of studies, many questions regarding the optimization of the training plan and specific target of the training stimulus are not completely answered. Therefore, the goal of this chapter is providing an overview of relevant literature, describing match activities, physiological demanding, and match-related fatigue highlighting the principal issues regarding training strategies and soccer training periodization.

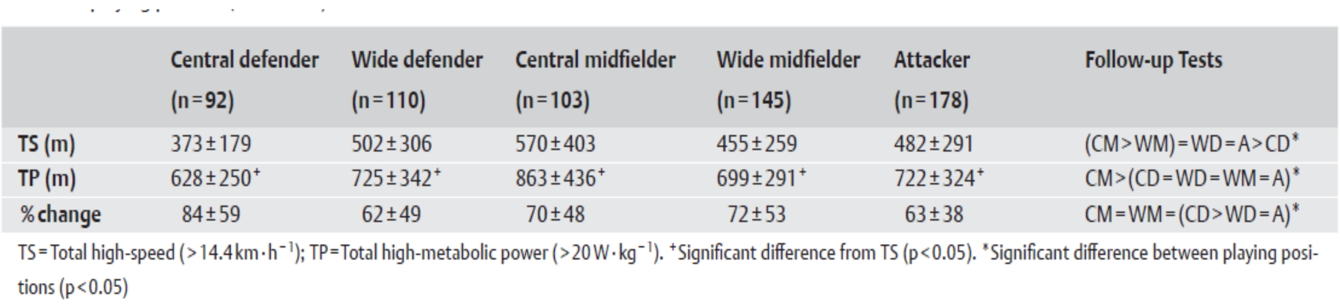
1.1 Match activities and physical demands

The match-analysis has always been considered crucial in identifying the physiological demands of the team sports. Understanding the physiological load imposed on top-level soccer players during competitive matches (activity profile, distance covered, intensity, energy systems, and muscles involved) is necessary to develop a sport specific training protocol, especially in elite athletes, where the most important form of training is that which matches energy use and biomechanics of an intended competitive performance [7].

The first analysis of the match-play activities was performed in the 1970s and it was continually updated with the introduction of new technologies and methods to quantify the energy expenditure and biomechanic demands [2, 7-9]. These studies reported that the typical distance covered by a top-class outfield player during a match ranges from 10 to 14 km, with differences related to rank and role [7]. The distance is covered with an intermittent exercise pattern by soccer-related actions such as jumping, kicking, tackling, turning, sprinting, changing pace, and sustaining forceful contractions to maintain the control of the ball [1]. Throughout the match, soccer players alternate short-high intensity exercise (~30% of the total match duration) with brief periods of low-intensity exercise (~70% of the total match duration) [10]. High-intensity running (>19.8 km·h^{-1}) account for 1-10% of the total distance covered during a match, and comprehend activities that are considered crucial for the game, such as agility task movements to win the ball to go past the opponents [11-13]. For this reason, it was suggested that high-intensity running distance could be a valid measure of physical performance in soccer and it is sensitive to the physiological changes associated with the completion of a training programme [14]. However, covering a greater high-intensity running distance does not represent the success of a team. Indeed, several studies reported that, at the same level of competition, less successful teams cover a greater high-intensity running distance than more successful teams [10, 15]. Therefore, an assessment of the physical-performance focused only on the quantification of the high-intensity running distance could be not appropriate to evaluate the physical performance during the match-play [16].

In the last decades, the quantification of the energy cost throughout the implementation of new technology (i.e., global position system, GPS; accelerometers) allowed to indirectly estimate the metabolic load, not only in relation to speed, but also taking into account accelerations and decelerations [9]. This approach showed that a great metabolic load is imposed on players not only when player run at high speed but also every time acceleration is high, even when speed is low [9]. For example, Gaudino et al 2013 [17] have compared the total high-intensity distance covered during a training session, using both high-speed running (> 14.4 km · h $^{-1}$; TS) and high-metabolic power (> 20 W · kg $^{-1}$; TP), relative to playing position. The results of this study showed that the traditional measurements of running speed alone underestimated the total energy demands of soccer training, especially in training sessions or playing positions associated with less high-intensity **(Table1.1)** [17]. However, despite this method improved the quantification of energy expenditure during match-play, it presents some limitations on the actual estimation of the net metabolic demand (especially during resting phases), and on the reliability of the measures [18, 19]. Despite this limitations, the widespread use of accelerometers and GPS for monitoring training and matches has allowed professional staff to quantify the training load with more accuracy, giving information helpful to improve the training prescription.

Table 1.1: Total high-intensity training distance covered estimated from high-speed running (> 14.4 km·h^{-1} ; TS) and high-metabolic power (> 20 W · kg^{-1}; TP), relative to playing position (mean ± SD) during the same training session. *From the works by Gaudino et al., 2013[17].*



	Central defender (n=92)	Wide defender (n=110)	Central midfielder (n=103)	Wide midfielder (n=145)	Attacker (n=178)	Follow-up Tests
TS (m)	373±179	502±306	570±403	455±259	482±291	$(CM>WM)=WD=A>CD^{*}$
TP (m)	$628\pm250^{+}$	$725\pm342^{+}$	$863\pm436^{+}$	$699\pm291^{+}$	$722\pm324^{+}$	$CM>(CD=WD=WM=A)^{*}$
% change	84±59	62±49	70±48	72±53	63±38	$CM=WM=(CD>WD=A)^{*}$

TS=Total high-speed (>14.4 km·h^{-1}); TP=Total high-metabolic power (>20 W·kg^{-1}). $^{+}$Significant difference from TS ($p<0.05$). *Significant difference between playing positions ($p<0.05$)

Parallel to the analysis of the activity profile, several studies have evaluated the physiological demand of the match-play [10, 12, 20]. The analysis of some physiological parameters (i.e., heart rate, blood lactate concentration) showed that the average work-intensity during the match is close to anaerobic threshold (situated around 80-90% of maximal heart rate) and elicits blood lactate concentrations of 4-6 mmol/L [10, 20]. However, these mean values of blood lactate concentration and heart rate do not reflect the intermittent nature of the game and purely describe some aspect of the physical demand [2]. For example, the rather high blood lactate concentration regularly seen in soccer [12, 21, 22] may not represent a high lactate production in a single action during the game, but rather an accumulated/balanced response to a number of high-intensity activities. Furthermore, the heart rate response during the repeated action may not represent the precise activities pattern [2].

To date, the only information available regarding the physiological demands and metabolic responses of repeated intense exercise were performed under control condition (i.e., laboratory) [23-26]. These studies, although not completely representative of the soccer performance, reported that during multiple-short bout of maximal-intensity exercise the energy production is derived primarily via anaerobic pathways in the first sprints, with an increasing in aerobic contribution at the end of exercise and at the increasing of the number of sprints performed [23, 26]. For instance, Gaitanos et al. (1993) [26]reported no changes in muscle lactate between the tenth and the last sprint during 15 sprints of 6 seconds, despite a partially maintenance of sprint performance, highlighting the importance of the aerobic metabolism during subsequent sprint. Additionally, other studies observed that players with high maximal oxygen uptake and high lactate threshold were able to more rapidly resynthesize phosphocreatine between repeated sprints [27-29]. However, despite these studies help to understand the energy contribution of metabolisms, the high number of factors involved, such as metabolic (i.e., H^+ buffering and Na^+/K^+ transport capacity) and neuromuscular factors (i.e., neural drive or motor unit activation), make this topic very complex and not fully understood [30]. Especially the multifactorial of this type of performance needs a careful choice of training methods. Therefore, in the next paragraph a better explanation of the current training methods will be performed.

1.2 Training characteristics and methods

The assessment of match activities showed that short-duration sprints (≤10 seconds) are frequent (e.i., sprint or high-intensity activity in less than 60s) during a soccer match [6]. The ability to produce the best possible average sprint performance over a series of sprints, separated by short (≤60 seconds) recovery periods have been termed repeated-sprint ability (RSA) [6]. In soccer, the mean time recorded during an RSA test predicts the distance of high-intensity running (>19.8 $km \cdot h^{-1}$) [14], and the total sprint distance during a professional soccer match. Additionally, the sprint percentage of decrement (e.g., sum of sprints divided for the best sprint) and total time of sprint during RSA test reflect players physical characteristics and differ from gender, with female that recorded low time sprint decrement compare to male [24, 31].

RSA is a complex fitness component that depends on both metabolic (e.g., oxidative capacity, phosphocreatine recovery and H+ buffering) and neural factors (e.g., muscle activation and recruitment strategies) [6]. In soccer, a widespread training practice is focused on the enhancement of RSA through the maximization of the high-power output or the minimization of the performance deterioration. The purpose is to “isolate” training contents targeting specifically neural or metabolic factors. For example, strength and power training was used to improve maximal activities (i.e., jumping, change of direction, acceleration), while aerobic training provided a stimulus necessary for the rapidly resynthesize of phosphocreatine between bouts [1, 12]. Although this approach is considered by many authors to be more effective [6, 32], recently, different “mixed” training approaches, (targeting both neural and metabolic factors simultaneously) have been proposed with team-sport athletes. These forms of training differ from each other for the sprint intensity, sprint duration, and recovery between bouts **(Figure 1.1).**

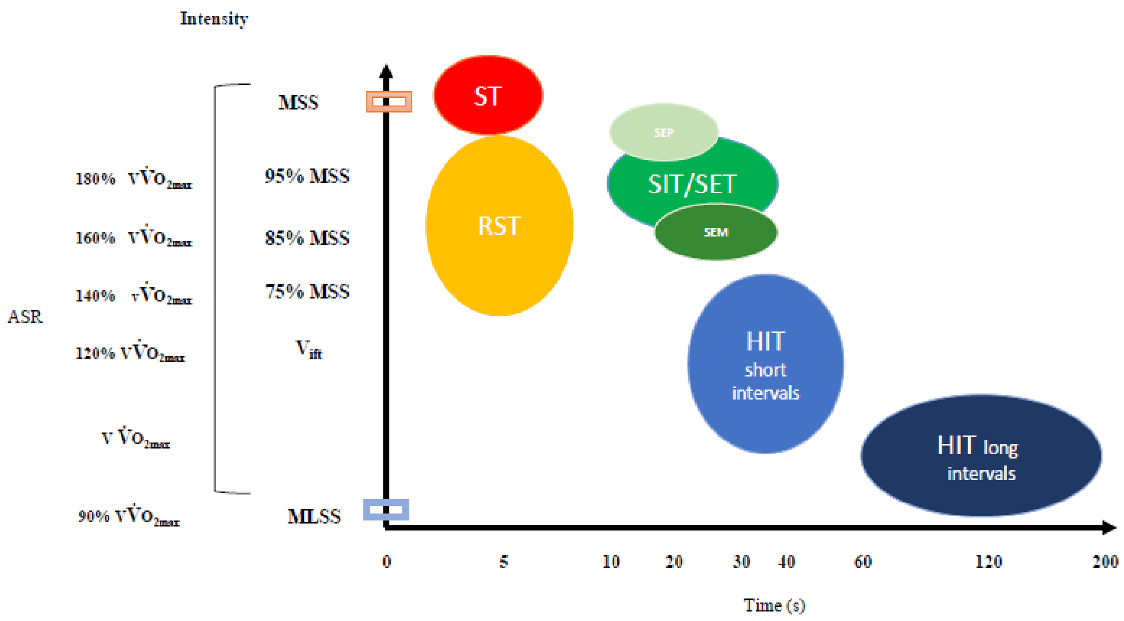


Figure 1.1: Intensity range and sprint duration used for the various run-based HIT formats. *ASR anaerobic speed reserve, MLSS maximal lactate steady state, MSS maximal sprinting speed, RST repeated sprint training, SIT sprint interval training, SET speed endurance training, SEP speed endurance production,* $\dot{V}O_{2max}$ *maximal oxygen uptake,* $v\dot{V}O_{2max}$ *minimal running speed required to elicit* $\dot{V}O_{2max}$*, SEM speed endurance maintenance,* V_{IFT} *peak speed reached at the end of the 30–15 Intermittent Fitness Test (data from Buchheit and Laursen, 2013b, [39]).*

The manipulation of only one of these training variables generates different forms of training such as high-intensity-interval-training (HIT), repeated-sprint training (RST), sprint intermittent training (SIT), and sprint training (ST) [33-37] **(Table 1.2).**

Each of these forms of training has a likely different effect on the acute physiological response, despite a similar improvement on RSA performance [38, 39]. For example, Mohr at al. (2007) [36] reported an improvement of 4.3% in sprint decrement in RSA performance after speed endurance training and 2.4% after ST, although differences between groups were found in blood lactate concentration, heart rate responses and muscular adaptation. Likewise, Iaia et al. (2017) [34]showed an improvement in total sprint time during RSA test of 3.7% and 4.6% after two protocols of RST. However, despite similar percentage of improvement on RSA performance, these training methods based on RST and SIT differently target the other physical capabilities such as sprint performance (i.e., 20 m and 200 m sprint performance), anaerobic threshold, and the ability to perform high-intensity intermittent exercise (i.e., Yo-Yo intermittent recovery test lv 2) [33, 35, 40].

Table 1.2: summarizing table of the different characteristics of HIT, RST, SIT and ST.

	Intensity	**Bout duration**	**Recovery work: recovery ratio**
High-intensity-interval-training (HIT)	90 -120% $v\dot{V}O_{2max}$	>40 s	1:0.5- 1:1- 1:2
Sprint intermittent training (SIT)	160 % $v\dot{V}O_{2max}$ All out	10 to 40 s	>1:5 (SEP) <1:4 (SEM)
Repeated-sprint training (RST)	All-out	<10 s	1:2 to 1:6
Sprint training (ST)	All-out	< 6 s	>1:6

In conclusion, it appears clear that there is more than one way to improve RSA performance by providing different physiological stimuli, despite it remains unknown which is the best training strategy for improve RSA. Therefore, further researches are needed to understand the acute response to various training formats and assist coaches and practitioners with the selection of the most appropriate training session to apply, at the right place and time.

1.3 Match-related fatigue in soccer

In soccer, players are subjected to continuous physical stimuli that can alter physiological status, affecting performance. Preparedness is defined as the difference between the levels of fitness (i.e., training level and ability to tolerate loads) and accumulated fatigue [41]. Preparedness mainly decreases after matches or high training load and return to optimal levels only after appropriate recovery periods and/or adequate training load reduction [41]. Therefore, understanding which are the factors that lead to decrease players preparedness and their recovery profile may help to develop conditioning programs.

Soccer is a physically and psychologically demanding sport that lead to a physical performance decrement, known as fatigue [42]. This high demand may prompt transient fatigue during match-play (e.g. after the most demanding 5-min period of the game) and exacerbate post-match residual fatigue towards match end (e.g. last 15-min period of the game), implying that a several days are needed to fully recover [2, 20]. Neuro-mechanical alterations, physical performance impairments, perturbations in the biochemical milieu and worsened psychometric state are often reported acutely and, in the days, post-match [3]. However, despite it appears clear that soccer players experience fatigue, the physiological mechanisms underlying these performance declines are sometimes without a clear consensus.

Temporary fatigue, fatigue at the end of the game, and post-match residual fatigue were widely studied [2, 20]. Temporary fatigue might be related to the depletion of muscle creatine phosphate, changes in intramuscular acidosis or accumulated potassium in muscle interstitium [2, 20]. Indeed, during the most intense period of the game, it has been observed that blood lactate concentration could achieve 12 $\text{mmol}\cdot\text{L}^{-1}$ with a markedly elevate muscle acidosis [43]. Therefore, it could be suggested that temporary fatigue during a game may be related to high muscle lactate concentrations and muscle acidosis. However, muscle lactate concentrations during the game were rather low (on average 20 $\text{mmol} \cdot \text{kg}^{-1}$ dry weight) compared with those found at exhaustion after high-intensity exercise [26, 44]. Furthermore, when athletes perform an intense intermittent exercise to exhaustion, the muscle lactate and pH recorded 1.5 min before the end of exercise were not different from those seen at exhaustion [45]. Thus, it remains unclear if muscle lactate and lowered muscle pH cause fatigue during a soccer game [45]. Indeed, despite these results seem suggest that muscle lactate and lower pH are not critical factors for the developing of fatigue, other studies reported that the glycolytic enzymes are inhibited by unbuffered acidosis [46].

Another hypothesis suggested that the development of temporary fatigue may be due to low muscle creatine phosphate concentrations. It has been shown that after intense periods in soccer the decrease in muscle creatine phosphate is significantly correlated with impairment in sprint ability [23, 25]. Additionally, it has been suggested that the development of fatigue during high-intensity exercise is associated with an accumulation of potassium in the muscle interstitium [47]. However, up-to-date little is known about potassium turnover in the muscle during a soccer game. Thus, it appears that temporary fatigue arises from a combination of several factors involving different mechanisms [42, 48].

The fatigue at the end of the game is influenced by a combination of several factors. In a soccer player, muscle glycogen is probably the most important substrate for energy production [49]. Indeed, several studies demonstrated that the development of fatigue during prolonged intermittent exercise is associated with a lack of muscle glycogen, while elevating muscle glycogen using a carbohydrate diet, elevates performance during such exercise **(Figure 1.2)** [43, 44, 50]. However, glycogen depletion is not the only factor that may contribute to the development of fatigue in the last stages of a soccer game. Other factors such as dehydration and muscle damage may also contribute to the development of fatigue [49, 51, 52].

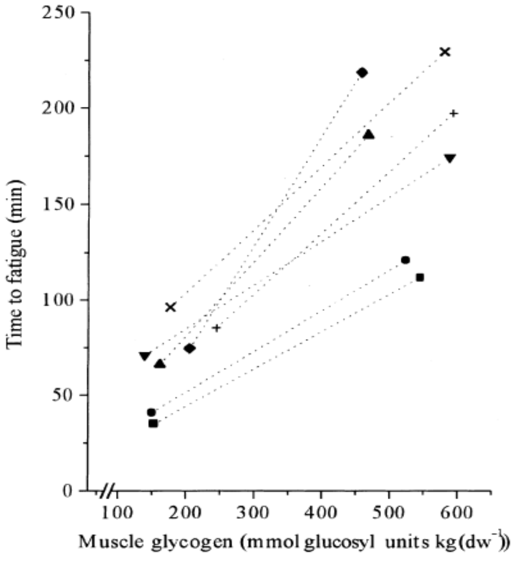


Figure 1.2: Relationship between pre-exercise muscle glycogen concentrations (m. vastus lateralis) and time to fatigue (sum of work and rest periods) for each of the seven subjects during the prolonged intermittent exercise protocol *(data from Balsom et al. 1999). [50]*

For example, studies reported that a negative fluid balance reduced sprint performance and maximal oxygen uptake when hypohydration is amounting to 2.7% of body mass [51, 53]. The repetition of changes of direction, accelerations, and decelerations throughout a soccer match induces muscle damage leading to a marked inflammatory response and may cause reduced maximal force-generating capacity [49].

In addition to the neuromuscular aspects, high level of psychological stress was recorded after the match [49]. In fact, during a match, the playing environment is continually changing: players must pick up information regarding the ball, teammates, and opponents before deciding on an appropriate response based upon current objectives (e.g., strategy, tactics) and action constraints (e.g., technical ability, physical capacity). Working on cognitively demanding tasks for a considerable time often leads to mental fatigue, which can impact performance [54]. Although it was reported that fatigued individuals are still able to perform highly over-learned and automatic skills, their performance significantly decreases when tasks require the voluntary allocation of attention [55]. However, although these hypotheses would reflect the causes of fatigue at the end of the match, the information regarding the relation between these factors are lacking.

Post-match residual fatigue is the decline in performance that can remain for hours and days following the match. The time course of physical performance recovery following a competitive match, friendly match, and simulated soccer exercise are presented in **Figure 1.3.**

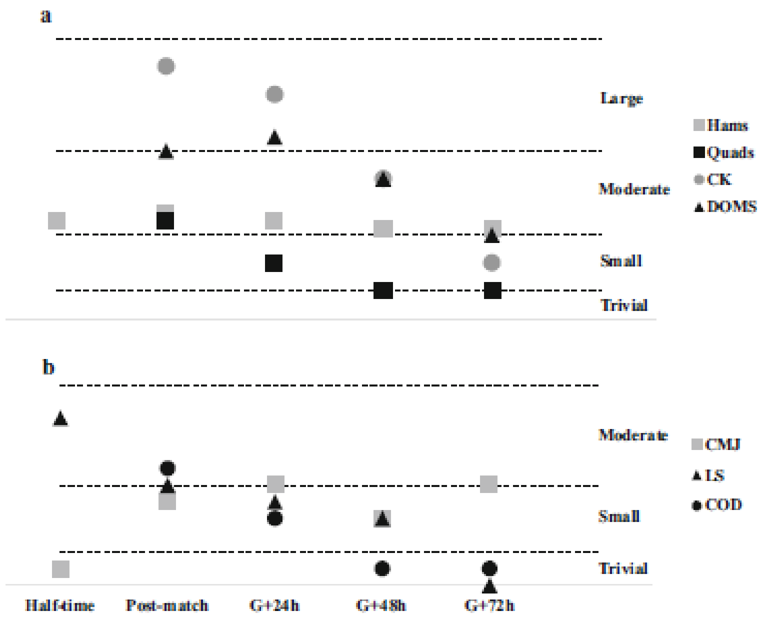
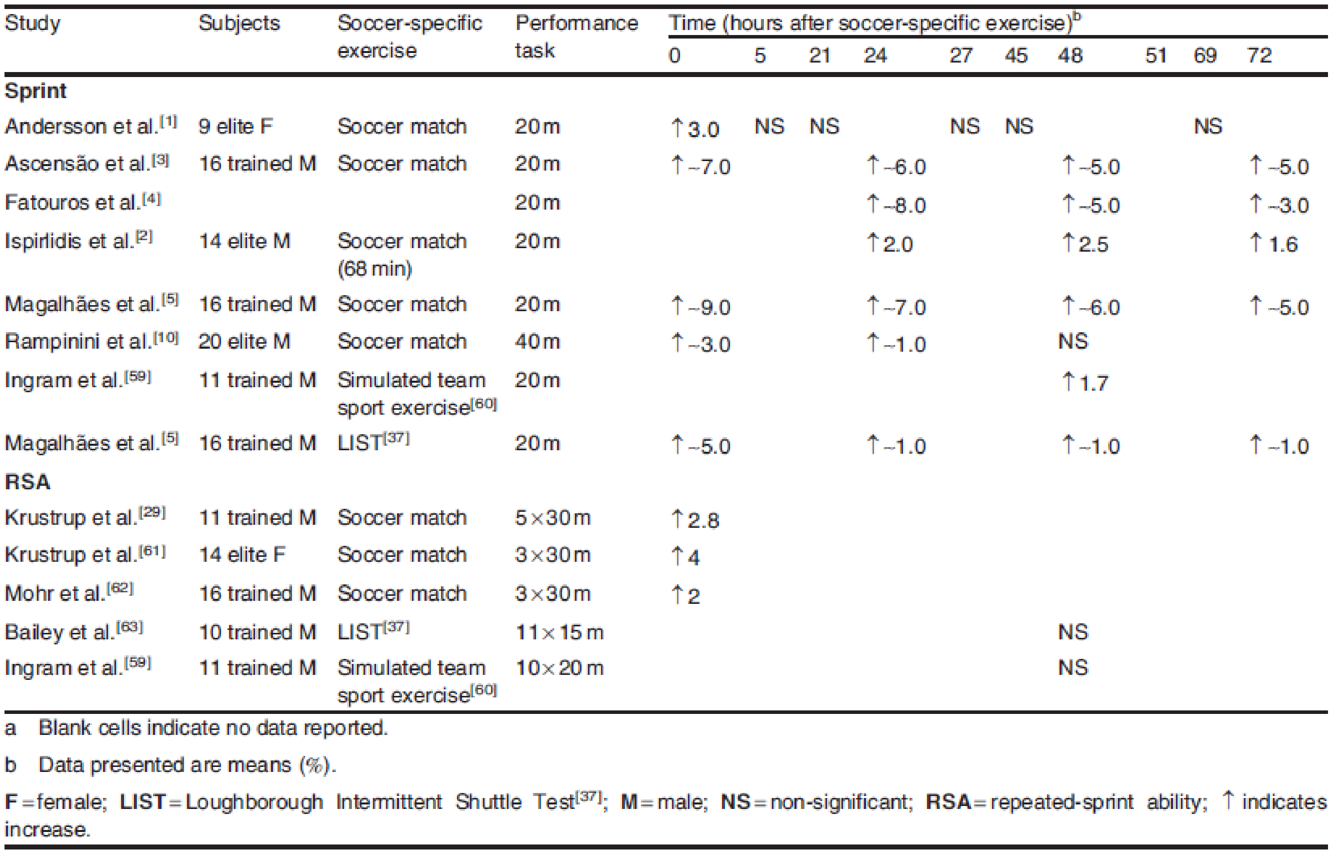


Figure 1.3: Time-course of standardized changes (average weighted effect sizes) in neuromuscular, biochemical and perceptual measures. *Time points: half-time, immediately (Post), one (Game + 24 h), two (Game + 48 h) and three (Game + 72 h) days after the match. A Hamstrings (Hams) and quadriceps (Quads) muscle strength, creatine kinase (CK) and delayed onset muscle soreness (DOMS); b physical performance assessed by the countermovement jump (CMJ), straight line sprint measures (SL) and change of direction ability (COD) (data from Silva et al. 2018)[3]*

Sprint performance is impaired immediately after exercise by -2% to -9% **(Table 1.3).** However, the recovery of sprint performance differs largely between studies with completed recovery occurring between 5 and 96 hours, depending on the study protocols. When the assessment is performed immediately after the match, jumps performance decrements ranges from 1 to -12%, while is fully recovered from 48 hours to more than 72 hours after the match. Nevertheless, there are some conflicting reports regarding the time course of recovery of muscle function and selected performance-related components (e.g., jump vs. sprint ability) [3]. Thus, an antireductionist approach must be adopted to understand the several intrinsic (e.g., age, training history, playing position) and extrinsic factors (e.g., competition level, opposition standard, match importance, number of recovery days from previous match) that likely influence the external and internal load experienced by each individual player with a consequent impact in the recovery time-course [3, 49].

Table 1.3: Recovery time course for single sprint and repeated-sprint ability following soccer-specific exercise. *(Data from Nedelec et al., 2012) [49]*



Study	Subjects	Soccer-specific exercise	Performance task	Time (hours after soccer-specific exercise)^b									
				0	5	21	24	27	45	48	51	69	72
Sprint													
Andersson et al.[1]	9 elite F	Soccer match	20 m	↑3.0	NS	NS		NS	NS			NS	
Ascensão et al.[3]	16 trained M	Soccer match	20 m	↑–7.0			↑–6.0			↑–5.0			↑–5.0
Fatouros et al.[4]			20 m				↑–8.0			↑–5.0			↑–3.0
Ispirlidis et al.[2]	14 elite M	Soccer match (68 min)	20 m				↑2.0			↑2.5			↑1.6
Magalhães et al.[5]	16 trained M	Soccer match	20 m	↑–9.0			↑–7.0			↑–6.0			↑–5.0
Rampinini et al.[10]	20 elite M	Soccer match	40 m	↑–3.0			↑–1.0			NS			
Ingram et al.[59]	11 trained M	Simulated team sport exercise[60]	20 m							↑1.7			
Magalhães et al.[5]	16 trained M	LIST[37]	20 m	↑–5.0			↑–1.0			↑–1.0			↑–1.0
RSA													
Krustrup et al.[29]	11 trained M	Soccer match	5×30 m	↑2.8									
Krustrup et al.[61]	14 elite F	Soccer match	3×30 m	↑4									
Mohr et al.[62]	16 trained M	Soccer match	3×30 m	↑2									
Bailey et al.[63]	10 trained M	LIST[37]	11×15 m							NS			
Ingram et al.[59]	11 trained M	Simulated team sport exercise[60]	10×20 m							NS			

a Blank cells indicate no data reported.

b Data presented are means (%).

F = female; **LIST** = Loughborough Intermittent Shuttle Test[37]; **M** = male; **NS** = non-significant; **RSA** = repeated-sprint ability; ↑ indicates increase.

1.4 The soccer training plan

Another crucial component for the physical-performance is the optimization of the training plan. Periodization can be considered a process of structuring training into phases to maximize athletes' chances of achieving peak performance and therefore their competitive goals [56]. In elite soccer, peaking performance for every match is not possible, due to the variety of training goals, the volume of concurrent training and practices, and the extended competition season [57]. Thus, soccer periodization aims to maintain the level of performance (performance stabilization) and manage the level of fatigue (fatigue management) throughout the season. To achieve this, periods of loading, unloading (recovery), and tapering (for the most important competitions of the year) must be sensibly arranged, and a planned variation of the training methods have to be performed. In soccer, the annual plan, or "season," can be divided into distinct periods: preparation phase (pre-season), competitive phase (in-season) and transition phase (off-season) [57].

Pre-season

The pre-season involves the maximization and evaluation of the training fitness level. During this phase, training focus is placed upon ensuring to increase players' key physical variables (e.g., aerobic endurance, strength speed, and power) and technical-tactical skills [12, 41]. The time availability and the absence of official competition concur to manipulate widely the total training load (product of training volume and intensity), to generate positive adaptation. Traditionally, soccer teams used to divide pre-season in two-part, with a first increase of training volume followed by a subsequent increase of intensity and volume reduction (linear periodization) **(Figure 1.4)** [58]. However, in modern soccer, the application of this pre-season schedule is becoming more complicated, due to the ever-increase presence of international tournament and commercial duty that have reduced the time available for the training. Thus, elite clubs have modified the training plan, introducing specific training sessions in the early stage of the pre-season, and using pre-season matches as training stimuli.

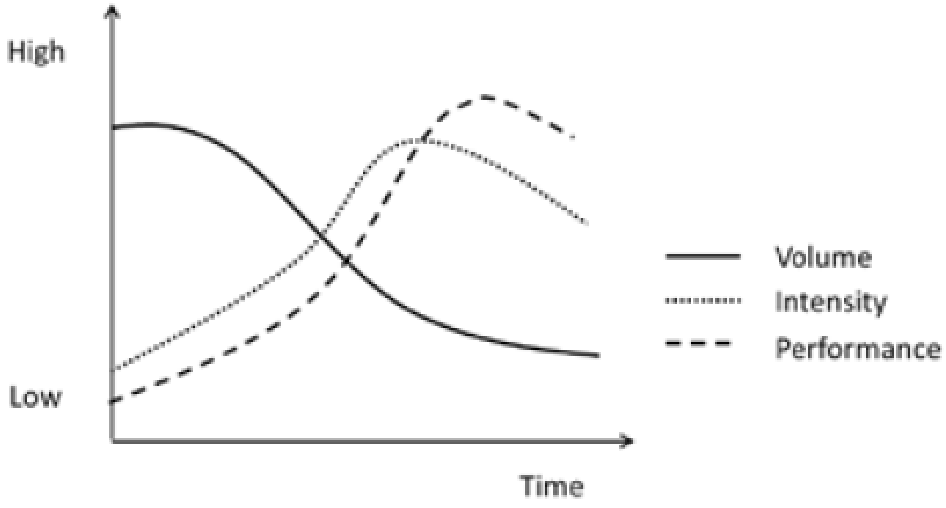


Figure 1.4. An example of linear periodization in which the volume decreases and the intensity increases. *[41]*

In-season

The in-season starts with the beginning of the national championship (e.g., Serie A, Ligue 1, Premier League, Bundesliga) and the extension depends upon the success of the club (e.g., Champions League, UEFA Cup, playout, playoff, national cup), as well as national federation (e.g., World Cup, European championship), and can account up to 70 matches. For this reason, elite soccer players are required to play every 3 to 4 days for a period that can exceed eight months. In this scenario, the periodization of the microcycle (representing the period that runs between two matches) becomes crucial [41]. The microcycle usually involves six days, but it could vary depending on the match schedule. The habitual activity of the microcycle entails match, recovery strategies, loading strategies, tapering and subsequent match [59]. Matches represent the higher physiological stimulus achieved during the in-season microcycle [59]. This training model is based on the fitness-fatigue model first conceptualized by Banister (1975) [60]. This model states that a training stimulus leads to two internal effects on the body: fatigue (a negative effect) and fitness (a positive effect). The principle holds that the fitness effect of training is relatively small but long-lasting, while the fatigue effect of training is shorter in duration but greater in magnitude. In this model, the two after-effects of training fitness and fatigue both influence the preparedness of the player **(Figure 1.5).**

The application of this model allows managing the fatigue development to optimize the level of preparedness for the consecutive match and stabilize the performance during the long duration of the in-season phase.

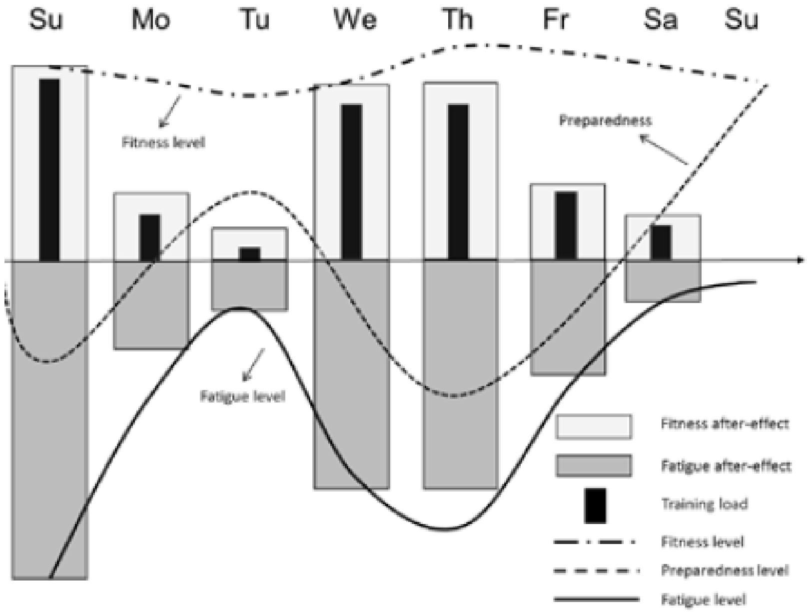


Figure 1.5: Fitness-fatigue effects during a microcycle in soccer. *The figure depicts the (accumulated) fitness and fatigue curves, the specific fitness and fatigue aftereffects of training and the resulting preparedness curve. [41]*

Off-season

The off-season phase includes the period after the end of the competitive phase, and it was suggested to be necessary for both psychological and physical reason [57]. This phase involves a break from training and allows the body and mind to full recovery before the next phase or training cycle. However, maintaining physical capabilities and body mass level is fundamental in this period. Indeed, researchers reported that a complete cessation of the training activity could make the detraining process very apparent. Thus, accordantly with Gamble, 2006 [57], it was suggested that players should participate to non-sport specific activity in order to maintain the physical fitness and interrupt the monotony of the usual training methods.

2° CHAPTER – Study 1

REDUCTION IN TRAINING LOAD 24 H BEFORE A MATCH IMPROVES PHYSICAL PERFORMANCE IN SOCCER PLAYERS

2.1 Introduction

In soccer, players should perform the match day in a maximal physical and physiological status. Unfortunately, peaking performance for every match is not possible, due to the variety of training goals, and the long duration of the season that reduces the time available for training [57]. Optimizing the training structure by manipulating volume and intensity may help to maintain the level of physical performance across the season [59]. The microcycle is the crucial part of the training plan and represents the period that runs between two matches [41]. It usually involves six full days, but it could vary depending on the match schedule. The habitual activity of the microcycle entails match, recovery strategies, loading strategies, tapering, and subsequent match. Match represents the higher physiological stimulus achieved during the microcycle [59] and is characterized by intermittent activities involving explosive actions such as sprints, jumps, dribbling, and kicking [2, 22]. High levels of fatigue are usually detected after a soccer match [20, 49], involving neuro-mechanical alteration (e.g., decrease in force production and power) [61], physical performance impairments (e.g., repeat sprint ability, intense intermittent-exercise, repeat jump) [11, 61, 62], perturbation in physiological markers (i.e., plasma myoglobin, creatine kinase, plasma total antioxidant status, blood leukocyte) [61-63], and depletion of muscle glycogen [2]. Thus, to cope with such physical demands, the training plan requires a careful balance between physical recovery and training to avoid excessive fatigue and maximize physical performance [41, 64].

Preparedness can be defined as the difference between fitness and fatigue (fitness – fatigue = preparedness) [41]. It dropped immediately following a high training load (increase level of fatigue masks the increase in fitness), and it is only after an adequate recovery and a reduced training load that the increases fitness levels can be seen. Therefore, an inappropriate periodization of recovery or a high training load (TL) session before the day of competition can negatively affect physical performance increasing the risk of injury [65], while an insufficient training stimulus may reduce the fitness level across the season [65].

Tapering is a typical periodization strategy characterized by a short-term reduction of training volume and frequency while intensity is maintained [66]. In soccer, tapering is habitually used within-microcycles and consists of a reduction in training volume during the days before a match [64]. Recently, several studies have illustrated various planning strategies showing a different reduction of the external training load [59, 67-70]. For example, Martín-García et al. (2018) [67], Stevens et al. (2017) [69] and Anderson et al. (2016) observed a progressive increase of TL until mid-week, and a subsequent decrease until the training day before a match. The higher training load was recorded 4 or 3 days before the match, while the lower load is performed the day before the match [67, 69, 70]. Conversely, Malone et al. (2015) [59] found that only the last training session before the match differed from other training days across several internal and external load variables. However, despite this wide diffusion of the tapering in the soccer training plan, there is still a paucity of information concerning the effectiveness of within-microcycle tapering on player preparedness. In particular, despite the literature describe the model theory regarding the effect of training load on fatigue and fitness [71], no studies have investigated the relation between training volume reduction and fatigue accumulation before the match. This absence of information is probably due to the different metrics used to quantify external training load, and the difficult to assess physical qualities the day of the match. The only studies available do not consider the within-microcycle tapering but investigate the effect of the alternative of 1 to 2-weeks tapering period [64].

For this reason, the first step for studying such processes would be monitoring the effect of different training load on the eve of match-day and then determining how the reduction of training load may be related to changes in various types of performance. Therefore, this study aims to examine the effect of a reduction in training load on player' preparedness (as measured by select physical performance parameters) 24 h before a match. We hypothesized that a training load reduction *per se* is not sufficient to improve the physical qualities and achieve the maximal level of physical capabilities on the day of the match.

2.2 Methods

Participants

Twenty outfield players from the same recreational team voluntarily agreed to participate. Inclusion criteria contemplated adequate training status (at least 6-8 h of training per week) and experience (a minimum of 7 years of experience in playing soccer), the absence of lower limb injuries within the last year, and absence of febrile illness at least six months before the study. Additionally, only players that performed at least 45 min in the previous match were considered. Nine players did not meet the criteria above and were excluded. Thus, eleven young male soccer players (age 17.0 ± 1 y, height 179.9±6.0 cm, body mass 70.0±8.4 kg) were recruited for this study. The players, parents or legal guardians were fully informed about the purpose and potential experimental risk and discomfort associated with the research before given their written informed consent to participate. The Ethical Committee of the local University approved the study in compliance with the Helsinki declaration.

Experimental Approach

A cross-over experimental design was used to assess the effect of a reduction in training volume on player preparedness. All participants underwent a 4-week (two sessions per week) familiarization period before starting the training intervention [72]. Data collection took place during the mid-season (January-February) involving two simulated match-week microcycles separated by two weeks of regular match schedule. The identical microcycle was performed for both experimental (EXP) and control (CON) conditions, except for EXP condition where the training time was reduced by ~33% during MD-1 (Table2.1). The simulated microcycles (5 days between matches) comprehended two training sessions (MD-3 and MD-1). To minimize post-match fatigue, two days of recovery post-match was performed, but no systematic recovery strategies were implemented (i.e., cryotherapy, compression garments, food intake). During MD-3, players performed a standardized training session (based on the regular training load performed during the season) with an identical technical-tactical request from the coaches **(Table 2.1)**. During MD-1, after the assessment of CMJ performance, different volume reduction was applied with the EXP condition that performed the 33% less of training time compared to CON. All the training session were monitored using a portable non-differential 10 Hz global position system (GPS) integrated with 400 Hz Tri-Axial

Accelerometer and 10 Hz Tri-Axial magnetometers (PLAYERTEK, Dundalk, Co Louth, Ireland). The devices were placed between the players' scapulae through a tight vest and were activated 15 minutes before the data collection, by the manufacturer's instructions to optimize the acquisition of satellite signals [73]. To avoid inter-unit error, players wore the same GPS device for each training session [74]. The physical demands of each training session for each player were evaluated through the assessment of sprint distance (> 19.8 $km \cdot h^{-1}$), Top speed ($m \cdot s^{-1}$), number of acceleration and deceleration above 3 $m \cdot s^{-2}$, and with the estimation of the energy cost (EC; in $J \cdot kg^{-1} \cdot m^{-1}$) and the associated metabolic power (P met; in $W \cdot kg^{-1}$) that were calculated by Osgnach et al. [9]. Furthermore, distance in zones at different metabolic power output (Distance power Zone, DPZ) was taken into consideration (5-10, 10-20, >20 $W \cdot kg^{-1}$).

Table 2.1: description of the training session.

MD-3	***Time***	**MD-1 (EXP)**	***Time***	**MD-1 (CON)**	***Time***
Warm up	*10 min*	Warm up	*10 min*	Warm up	*10 min*
Technical skills	*15 min*	CMJ test		CMJ test	
Small-side games 3x4min (5vs5 25x30m)	*20 min*	Boxing	*10 min*	Positioning drill	*15 min*
Tactics (10vs10 65x50m)	*30 min*	Shooting drill	*10 min*	Agility and Quickness drills	*15 min*
Aerobic intermittent drills 3x (9x15s rec 15s)	*15 min*	Tactics (10 vs 10 50x50m)	*10 min*	Tactics (10 vs 10 50x50m)	*20 min*

Matchday minus 3 (MD-3); Match day minus (MD-1); EXP experimental condition; CON control condition

Additionally, the session rate of perceived exertion (RPE) was determined by multiplying the RPE by training duration (minutes) (RPE-TL) as described by Foster et al. [75]. Each athlete's session RPE was recorded about 30 min after each training session. In this study, the Italian translation of the CR10-scale modified by

Foster et al. (16) was used. All athletes had been familiarized with this scale for rating perceived exertion before the beginning of the study.

Performance tests

Countermovement Jump:

Jump height was calculated from the flight time obtained by photoelectric cells as built-in one-meter long parallels bars (Optojump, Microgate, Bolzano, Italy) [76]. Players were instructed to keep their hands on their hips with the depth of the counter movement self-selected for all jumps. Each trial was validated by visual inspection to ensure each flight phase was without significant leg flexion, and a recovery of 2 min was given between trials. Only the best trials were considered for the analysis. Tests were carried out during MD-1 and MD. Throughout the assessment of the changes in jump performance it will be monitored the neuromuscular status of the player [77].

Repeat Sprint Ability test (RSA):

The RSA test was carried out using electronic timing gates (Witty, Microgate, Bolzano, Italy). The participants were instructed to perform as fast as possible each sprint (S). Players completed 5 repetitions of 30 m straight-line sprints interspersed with 25 s of passive recovery [40]. Total sprint time (RSA_t) and best sprint (RSA_{best}) for all 5 sprints were determined. Additionally, to quantify fatigue during the percentage decrement score (RSA_{dec}) was also included and calculated as follows [78]:

$$RSAdec = \left[\frac{S_1 + S_2 + S_3 \cdots + S_{final}}{S_{best} \times number\ of\ sprint} - 1\right] \times 100$$

The Yo-Yo Intermittent Recovery Test level 1:

The Yo-Yo Intermittent Recovery Test level 1 (Yo-Yo IR1) consists of 2 x 20-m shuttle runs at increasing speeds, interspersed with 10 s of active recovery, controlled by audio signals. The test terminated when the subject was no longer able to maintain the required speed, and the distance achieved was recorded as the final result [79].

Statistical Analyses

The normal distribution of each variable was examined with the Shapiro-Wilk test. Data were analyzed by one-way ANOVA with repeated measures to detect potential interactions. In case of significant interaction, multiple t-tests with Bonferroni adjustment were used further comparisons. The level of statistical significance was set for all analyses at $p < 0.05$. In addition to null-hypothesis testing approach, magnitude-based inference approach was also adopted to focus on the practical relevance [80]. For between-group changes, the chances that the true mean changes were beneficial (i.e., greater than the smallest worthwhile change, SWC [0.2 multiplied by the between-subject standard deviation]), unclear or harmful were considered. The corresponding quantitative chances of beneficial, unclear of harmful changes were evaluated as follows: 25-75%, *possibly*; 75-95%, *likely*; 95-99%, *very likely*; and >99%, *almost certainly*. If the chance of obtaining greater and poorer differences was both >5%, the true difference was assessed as *unclear*. To perform each calculation and interpretation related to the magnitude-based inference approach, customized spreadsheets, available at www.sportsci.org/index.html, were utilized. Data are presented as means ± SD, whereas relative changes are presented as means ±90% confidence intervals.

2.3 Results

At MD-1, CMJ performance was not significantly different between the two conditions. During MD the height of the jump improved by 4.8% ($p < 0.05$) in EXP condition, while no differences were recorded in CON **(Table 2.2)**. Significant differences between EXP and CON conditions were found in $RSA_{best,}$ and RSA_t, while no differences were recorded for RSA_{dec}. Distance covered during Yo-Yo IR1 was similar ($p > 0.05$) after both interventions.

Table 2.2: changes in performance following a reduction of training volume the day before the match

Physical variables	*CON*	*EXP*	Standardized differences *(Coen's d ±90% CI)*	Percent changes of worse/trivial/better performance	Qualitative inferences
CMJ - MD-1 (cm)	38.5±4.6	39.3 ± 4.3	0.16 ± 0.18	0/65/35	Possibly
CMJ – MD (cm)	38.8 ± 4.3	41.3 ± 4.5 *	0.50 ± 0.30	0/5/95	Very likely
RSA_t (s)	23.5 ± 0.5	22.9 ± 0.4 *	-1.23 ± 0.5	0/0/100	Almost certainly
RSA_{best} (s)	4.53 ± 0.1	4.45 ± 0.1 *	-0.74 ± 0.34	0/1/99	Almost certainly
RSA_{dec} (%)	3.7 ± 1.7	2.9 ± 1.6	-0.49 ± 0.69	5/18/77	Possibly
Yo-Yo IR1 (m)	1062 ± 319	1145 ± 395	0.17 ± 0.48	10/44/46	Unclear

*Countermovement jump (CMJ), Matchday -1 (MD-1), Matchday (MD), Total sprint time (RSA_t), percentage decrement score (RSA_{dec}), best sprint (RSA_{best}), Yo-Yo intermittent recovery test level 2 (Yo-Yo IR2); *Significant differences between conditions ($P < 0.05$)*

The analysis of the training session's characteristics is presented in **Table 2.3**. Training load was standardized during MD-3, and no differences were recorded in each internal and external training variable between intervention. During MD-1 an additional 33% of volume reduction was performed in EXP, compare to CON condition (~33% of volume reduction between MD-3 and MD-1 in CON condition, and ~66% between MD-3 and MD-1 in EXP condition). The comparison of the internal and external training load was also performed during MD-1. Data showed a significant difference in RPE-TL, total distance, sprint distance, numbers of acceleration >3m·s^{-2} DPZ 5-10, DPZ 10-20 and DPZ >20 W·kg^{-1}. No differences were found in RPE, and top speed reached during the two interventions

Table 2.3: Comparison of the internal and external training load performed during MD-3 and MD-1

Training Internal and external load	**MD-3**		**MD-1**	
	CON	*EXP*	*CON*	*EXP*
RPE	5.7 ± 1.1	5.7 ± 1.2	3.1 ± 0.9	3.2 ± 0.9
RPE-TL	510 ± 95	514 ± 111	185 ± 56	127 ± 34*
Distance (m)	6441 ± 1187	5926 ± 1194	4393 ± 772	3239 ± 270*
Sprint Distance (m)	623 ± 330	440 ± 318	168 ± 87	103 ± 43*
Top Speed (m·s^{-1})	7.0 ± 0.6	6.7 ± 0.4	6.7 ± 0.6	6.5 ± 0.5
DPZ: 5 - 10 W·kg^{-1} (m)	1822 ± 394	1640 ± 369	1564 ± 287	1164 ± 140*
DPZ: 10 - 20 W·kg^{-1} (m)	1562 ± 303	1663± 476	1021 ± 262	723 ± 144*
DPZ > 20 W·kg^{-1} (m)	1274 ± 417	1067 ± 467	480 ± 167	287 ± 62*
ACC > 3 m·s^{-2}	54 ± 25	39 ± 12	40 ± 15	23 ± 5*
DEC > -3 m·s^{-2}	44 ± 24	33 ± 14	30 ± 15	22 ± 7

*Match day minus 3 (MD-3); Match day minus (MD-1); EXP experimental condition; CON control condition; RPE rate of perceived exertion; RPE-TL rate of perceived exertion multiply for training duration; Distance power zone 5 to 10 W·kg^{-1} (DPZ 5 - 10 W·kg^{-1}), Distance power zone 10 to 20 W·kg^{-1} (DPZ 10 - 20 W·kg^{-1}), number of acceleration above 3 m·s^{-2} (ACC > 3 m·s^{-2}), number of deceleration above 3 m· s^{-2} (DEC > -3 m·s^{-2}); *Significant differences between conditions ($P < 0.05$)*

2.4 Discussion

The present study is the first that documented the time course of changes in neuromuscular and repeated intense exercise capacity in response to different within-microcycle tapering approach. The main findings highlighted that a higher decrease of TL during tapering could significantly improve the height of the jump, 30 sprint time and repeated 30m sprint performance. Conversely, the capacity to perform repeated incremental exercise measured with the Yo-Yo IR1 test was found to remain unchanged after the two tapering programs also when a 33% further reduction of TL was induced.

During MD-3, the TL was careful standardized to provide a similar physical status before the tapering approach. The GPS metrics were slightly lower what the usually reported in the mid of the week in elite male soccer players [67], but the RPE result similar [81]. Consequently, the results from this study can be regarded as representative for recreational male soccer players during a mid-microcycle session. The absence of significant differences observed in RPE and GPS metrics during MD-3, suggests that the use of standardizing training session generated similar external and internal training loads in the observed players. More importantly, the amount of high-intensity running and acceleration, which did not significantly differ between the two-training session. Additionally, the comparable results in the height of the jump recorded in MD-1 (before the different tapering intervention), confirmed that the studied players were in a similar physical status before the start of the experimental phase.

During MD, the CMJ, RSA test, and Yo-Yo IR1 test were performed to evaluate the time course of changes in neuromuscular and repeated intense exercise capacity in response to different tapering. Indeed, previous studies have shown that the height of the jump and sprint performance are valid measures to assess the neuromuscular fatigue in team-sports [82, 83], while Yo-Yo IR1 provided important information about aerobic level and repeated intense exercise capacity [79]. Therefore, the *very likely* and *almost certainly* beneficial effect reported on both height of the jump and RSA_{best} after EXP condition seems to suggest that higher volume reduction have a role in the decrease of accumulate fatigue. In accord with this suggestion, other researchers have observed improvements in anaerobic performance, lower limb muscle power, acceleration capacities and an increase in the neuronal drive after a period of volume restriction [64, 84].

However, these studies analyzed more extended tapering period, different sporting activities and no comparison between different training volume reduction was performed.

A possible explanation for the performance enhancement in the present study could be attributed to the 70% and 64% of the reduction in the total amount of acceleration and in sprint distance respectively, reported in the EXP compare to CON condition. Acceleration and sprint distance required a high-level of power and force production, that when are repeated for an extended period, can cause fatigue development [3, 85]. Several studies reported that this high demand may prompt performance decrement during the match and may also have an essential consequence on fatigue development and injuries risk [11]. Thus, limiting the exposition to this high-intensity activity the day before the match may reduce the accumulate fatigue, enhancing preparedness. Concordantly, Los Arcos et al. [86] showed a negative correlation between values of total exposure time to training and relative change in CMJ, and 15m sprinting speed. These investigators also reported that the players who perceived the prescribed training load as harder were more likely not to improve single leg CMJ performance as much as the players with lower perceived load [86]. Thus, it is perhaps surprising that the comparison of session RPE between-condition in this study does not reflex the decrease in training load. However, it could be possible that players could perceive physiological stimuli differently as a consequence of their psychological state or the proximity to the game [87].

The assessment of Yo-Yo IR1 showed maintenance of high-intensity intermittent capacity in both conditions. This absence of improvement was not in line with that observed by other studies after tapering [64, 84]. For example, Beltran-Valls et al. [64] showed improvement in high-intensity interval capacity, despite the use of a more extended tapering period. A possible cause of this absence of differences might be the pre-tapering level of muscle glycogen [11]. Although no biological data were recorded it is possible to speculate that, due to the standardization of MD-3, the level of muscle glycogen depletion were similar after training, and lower than after a match. Thus, the recovery day performed in MD-2 and the lower activities performed EXP, and CON condition may have allowed reaching the day of the match under the same conditions. Additionally, Anderson et al. [85] reported different time course of recovery between some biochemical parameters (e.i., uric acid and urea) compare to neuromuscular factor (e.i., the height of jump and sprint time), which would explain the possible differences observed. However, we cannot rule out the possibility that the reduction of training volume affects aspects of the performance or biochemical markers other than those measured in our study. For this reason, further research is needed to assess the physiological and biochemical marker after a period of tapering.

Conclusion

This study demonstrates the existence of differences in the recovery pattern of various soccer-related physical performance in response to different tapering. Furthermore, this study showed that a reduction of training load per se is insufficient to achieve the maximal level of physical capabilities on the day of the match, in young recreational soccer players.

Limitation of the study

In addition to the poor number of participants involved, the present study presents other limitation that should be acknowledged. For example, the recruitment of recreational soccer players and the use of a simulated microcycle is poor ecological and does not represent the habitually training load used by professional-soccer teams. Indeed, the use of few recovery days after the match and the only one day of high training load might have modified the accumulated fatigue. Additionally, further measurement of the soccer-match performance might be necessary for the analysis of the tapering effectiveness. Indeed, given the complexity of a soccer match, the physical improvement does not provide transference to match success after tapering since the physical condition is not the only main factor for soccer performance. However, the results found regarding the physical performance can be pivotal for further research that will investigate the tapering approach during the microcycle.

3° CHAPTER – Study 2

THE EFFECT OF SPRINT DURATION DURING SPRINT-ENDURANCE TRAINING ON CHANGES IN SOCCER-RELATED PHYSICAL PERFORMANCE IN MEN

3.1 Introduction

Optimizing training prescription is fundamental for soccer players and coaches, due to the relative high levels of physical performance required to cope with the ever-increasing energy demands of match play [88]. In soccer, certain levels of physical performance are required to generate and maintain power output during repeated high-intensity efforts [14, 24], and to reduce the performance decrement caused by fatigue [20]. Indeed improvements in physical performance are positively associated with some motion parameters (e.g., total distance, high-intensity distance, number of sprints) [89], and physiological adaptations (e.g., oxidative capacity, phosphocreatine recovery and H^+ buffering) [6, 31, 35, 90]. However, despite the increased research highlighting the importance of physical performance for soccer players [6, 88, 89], the multiplicity of physical characteristics to train, (e.g., aerobic power, speed, power, and speed), and the congestive match periods, require a careful selection of the training methods.

In recent years, research has highlighted that speed-endurance training is a potent strategy to increase the physical performance of soccer players [37, 91-93]. This training strategy is characterized by multiple, prolonged “all-out” bouts ≤ 40 s that are separated by comparatively long rest periods [92]. This type of training has been reported to improve short-term supramaximal [37, 91, 92, 94], medium- to long-term [37, 94, 95], repeated sprint [33, 40], and exhaustive high-intensity intermittent performances [96].

Adaptations to speed-endurance training depend on the type of sprint training undertaken [97]. Indeed, the bioenergetics of sprint bouts during speed-endurance training differ markedly depending on the recovery intervals, the sprint duration and intensity. For example, it has been reported that longer recovery intervals (work-recovery ratio > 1:5) allow the maintenance of a higher power output and have a greater effect on improvements in RSA and Yo-Yo intermittent recovery test performance [33, 40], while a reduction of sprint duration allows for a greater sprint power and induces greater adaptations in single-sprint performance [36].

Short-duration sprint exercise is associated with a high-power production during the first 2 to 3 seconds of exercise, due to a high-breakdown of stored muscle phosphagens (e.g., adenosine triphosphate (ATP) and phosphocreatine (PCR), followed by an increase in both aerobic glycolysis and aerobic metabolism [98]. Longer-duration sprints lead to a rapid decline of power [98], which is associated with a decrease in anaerobic energy production and a significant increase in the energy derived from aerobic metabolism [97]. However, while is clear that sprint duration affects the relative contribution of aerobic and anaerobic metabolism, the effect of the sprint duration on changes in soccer-related physical performance required further investigation.

Therefore, the aims of the present study were twofold: (i) to compare the physiological and power responses when different sprint durations are used during sprint-endurance training, and (ii) to examine the effect of different sprint durations on improvements in soccer-related physical performance. We hypothesized that a reduction of sprint duration (while maintaining the same work-recovery ratio of 1:6) would provide a greater stimulus to improve average speed during repeated-sprint exercise and to improve the ability to resist fatigue development and to sustain high-intensity intermittent performance. The results of this research will help athletes and coaches to prescribe speed-endurance training better to improve soccer-related physical performance.

3.2 Methods

Participants

Sixteen young male soccer players belonging to the same recreational team (age 18.0±0.8 y, height 179.9±4.8 cm, body mass 71.4±6.6 kg) were recruited for this study. Participants had a minimum of 7 years of experience playing soccer. Participants were fully informed of any possible risks and discomfort associated with the experimental procedures before giving their written informed consent. The local ethics committee approved the study.

Experimental Approach

To evaluate changes in physical performance induced by two different regimes of speed endurance training, we used a parallel, two-group, work-matched, longitudinal (Baseline-Test Post-test) experimental design. The participants were matched based on their baseline physical performances and randomly allocated to either the speed endurance production for 20 s (SEP 20; n = 8) or the speed endurance production for 10 s (SEP 10; n = 8) training group. The randomization process was based on the value achieved during each test. Each test attributed a score from 1 to 16 AU depending on the level of performance achieved. The participant achieves the best performance received 16 points the worst 1. the sum of the score determined the final score. on the basis of these values the subjects were allocated in the two groups. Data collection took place during the last part of the competitive season (April- May), and the protocol consisted of a familiarization period, 1 week of baseline testing (Pre), a 4-wk training intervention, and 1 week of final testing (Post).

During the 2nd and 8th training session, the players' external load was computed through GPS data, and players' internal-load computed through heart-rate (HR), blood lactate concentration (La), and ratings of perceived exertion (RPE). The performance tests at the beginning of the baseline as well as before and after the intervention period, included: i) an aerobic fitness test, ii) a 20-m sprint performance, iii) a repeated sprint test (RSA) iv) a 200-m sprint performance, and v) a Yo-Yo Intermittent Recovery Test Level 2 (Yo-Yo IR2).

SEP 10 training consisted of 6 to 12 reps of 10-s all-out bouts (2 x 30-m shuttle runs) interspersed with 60 s of passive recovery, while the SEP 20 protocol consisted of 3 to 6 reps of 20-s all-out bouts (3 x 40-m shuttle runs) interspersed by 120 s of passive recovery. In both experimental conditions, training volume increased with time and was not significantly different between SEP 20 and SEP 10.

Training monitoring

During the second and last training sessions, a blood sample (collected from the earlobe) was taken immediately after bouts number 1,2,3 and 5, and before the 5th bout, in SEP 20, and immediately after bouts number 1,4,6 and 10, and before the 10th bout, in SEP 10. Lactate concentration [La$^-$] was subsequently analyzed in these blood samples using a portable lactate analyzer (Lactate Plus, Nova Biomedical, Waltham, MA, USA). Sprint time was also recorded for each shuttle run with portable photoelectric cells (Witty, Microgate, Bolzano, Italy), and the players' external-load was computed using global position system (GPS) technology (10 Hz, Playertek, Dundalk, Co Louth, Ireland). A heart rate monitor connected to the GPS system recorded heart rate during these training sessions. Heart rate data ware reported as a percentage of the maximal heart rate (HRmax) HR means, HR peak and time spent at greater than 85% of HRmax (HRmax was estimate based on the maximal HR reach during the Yo-Yo IR 2)

GPS collection and analysis

The player' s physical activity during each training session was monitored using Playertek pods (GPS and accelerometers; 400 Hz tri-axial integrated) placed between the player's shoulder blades. To increase the validity of the measure, all devices were activated 15 min before the start of the training session to allow the acquisition of satellite signals [73]. In order to avoid inter-unit error, players wore the same GPS device throughout the experiment [73]. The physical demands of each training session for each player were computed using these physical parameters: sprint distance (speed > 19.8 $km \cdot h^{-1}$), top speed ($m \cdot s^{-1}$), number of acceleration and deceleration between 3 to 4 $m \cdot s^{-2}$, number of accelerations and decelerations > 4 $m \cdot s^{-2}$. We then estimated the energy cost (EC; in $J \cdot kg^{-1} \cdot m^{-1}$) and the associated metabolic power (P met; in $W \cdot kg^{-1}$) [9].

Performance tests

Performance tests took place on four different experimental days. All players were familiarised with the testing procedures before the initial testing. Participants abstained from strenuous physical activity and alcohol or caffeine consumption from 24 h before testing, and they followed a nutritional strategy designed to ensure an adequate carbohydrate intake (~60% of total energy intake); this was recorded and replicated during the subsequent testing days.

Aerobic fitness test

A submaximal aerobic fitness test was performed on natural turf and consisted of 6 min of running at a constant speed of 13.5 $km \cdot h^{-1}$ [99]. A capillary blood sample was collected from the earlobe immediately after the end of the test and [La^-] was subsequently analyzed.

20-m sprint test

The day after, a short sprint performance was evaluated over 20-m distances on the natural ground. Time was recorded using photoelectric cells (Witty, Microgate, Bolzano, Italy). Players started the sprint from a standing position with the front foot placed 10 cm before the first timing gate. Only the best performance over three trials was used for further analysis. Each 20-m sprint was separated by 150 s of passive recovery [33].

RSA test

Following the 20-m sprint test (after 10 min of recovery) participants performed an RSA test consisting of 5 repetitions of 30-m all-out sprints interspersed by 25 s of passive recovery. Time was measured with photoelectric cells (Witty, Microgate, Bolzano, Italy). Best sprint time (RSA_{best}) and total sprint time (RSA_t) for the five sprints (S_1, S_2, S_3, …) was determined. Also, to quantify fatigue during the RSA test, the percentage decrement score (RSA_{dec}) was calculated as follows [100]:

$$RSAdec = \left[\frac{S_1 + S_2 + S_3 \cdots + S_{final}}{S_{best} \times number\ of\ sprints} - 1\right] \times 100 \tag{1}$$

200 m sprint test

An all-out run was performed over 200 m. Time recordings were obtained using photoelectric cells (Witty, Microgate, Bolzano, Italy). Participants performed only one, all-out sprint.

Yo-Yo IR2 test

The Yo-Yo Intermittent Recovery Test level-2 was performed. The test consists of 2 x 20-m shuttle runs at increasing speeds, interspersed with 10 s of active recovery, controlled by audio signals. The distance achieved was recorded when the participants were no longer able to maintain the required speed [79].

Statistical Analyses

Data were analyzed using a two-factor repeated-measure ANOVA with one between factor (group: SEP 20 vs. SEP 10) and one within factor (time: Pre-vs Post). An unpaired t-test was used to see the difference between-groups for each time point (i.e., Pre and Post). The level of statistical significance was set for all analyses at $p < 0.05$. Threshold values for Cohen ES statistic were >0.2 (small), 0.2 to 0.5 (moderate) and >0.8 (large). The normal distribution of each variable was examined with the Shapiro-Wilk test.

In addition to null-hypothesis testing, a statistical approach based on the magnitudes of change was also utilized [80]. For between- and within-group comparisons, the chances that the true mean changes following each training program were worse, unclear/trivial, or better for performance. Quantitative changes of worse, trivial, or better changes were evaluated qualitatively as follows: <1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possibly; 75–95%, likely; 95–99%, very likely; and >99%, almost certainly. If the chances of having improvement or impairment performance changes were both >5%, the true difference was defined as unclear [80]. Moreover, to calculate the effect size (ES) for the changes in each performance parameter between SEP 20 and SEP 10 group, the pooled pre-training standard deviation was used [101]. Raw data are presented as means ± SD, whereas relative changes are presented as means ±90% confidence intervals.

3.3 Results

Performance

Pre-intervention performance parameters were not significantly different between the two groups **(Table 3.1)**. Post-intervention, there were no significant changes in 20-m sprint time, RSA_{dec}, 200-m sprint time or $[La^-]$ at the end of an aerobic fitness test for either group. The RSA_t decreased by 1.1% and 1.5% following the training intervention, in SEP 20 and SEP 10, respectively ($p < 0.05$). In SEP 20, RSA_{best} was 1.7% lower ($p < 0.05$) following the intervention, with no significant differences for SEP10 ($p = 0.14$). The Yo-Yo IR2 performance improved by 10% and 16% in SEP 20 and SEP 10, respectively ($p < 0.05$). Between-group changes are presented in **Figure 3.1.** Changes in RSA_t were possibly better in SEP 10 than those observed in SEP 20.

Table 3.1: Changes in performance following speed endurance training consisting of different sprint durations. *Speed endurance production for 10 s (SEP 10), Speed endurance production for 20 s (SEP 20), Total sprint time (RSAt), percentage decrement score (RSAdec), best sprint (RSAbest), Yo-Yo intermittent recovery test level 2 (Yo-Yo IR2).*

	SEP 10					SEP 20				
	Pre	Post	Standardized differences (Coen's d ±90% CI)	Percent chances of worse/trivial/better performance	Qualitative inference	Pre	Post	Standardized differences (Coen's d ±90% CI)	Percent chances of worse/trivial/better performance	Qualitative inference
Aerobic Test (mmol·L^{-1})	7.4 ± 1.6	6.9 ± 1.8	-0.34 ± 0.60	7/27/67	Unclear	8.5 ± 2.5	8.2 ± 1.7	-0.03 ± 0.42	17/59/23	Unclear
20-m sprint time(s)	3.11 ± 0.15	3.05 ± 0.12	-0.32 ± 0.32	1/25/74	Possibly	3.13 ± 0.1	3.1 1± 0.11	-0.24 ± 0.25	1/39.2/60	Possibly
RSAbest (s)	4.45 ± 0.19	4.40 ± 0.16	-0.24 ± 0.28	1/38/61	Possibly	4.45 ± 0.16	4.39 ± 0.18 *	-0.36 ± 0.27	0/15/85	Likely
RSAt (s)	23.2 ± 0.9	22.9 ± 0.8*	-0.34 ± 0.23	0/14/86	Likely	22.9 ± 0.8	22.7 ± 0.7 *	-0.23 ± 0.16	0/38/62	Possibly
RSAdec (%)	4.1 ± 1.6	4.2 ± 1.3	0.12 ± 0.74	43/36/22	Unclear	2.9 ± 0.7	3.8 ± 1.7	0.53 ± 1.04	71/17/11	Unclear
200-m sprint time (s)	28.0 ± 1,3	27.6 ± 1,2	-0.28 ± 0.34	1.7/32/66	Possibly	28.0 ± 1.4	27.9 ± 1.0	-0.05 ± 0.36	11/66/23	Unclear
Yo-Yo IR2 (m)	370 ± 126	440 ± 111 *	0.51 ± 0.38	0/8/92	Likely	410 ± 87	460 ± 90 *	0.49 ± 0.36	0/8/91	Likely

* Significant difference Pre-Post ($p < 0.05$).

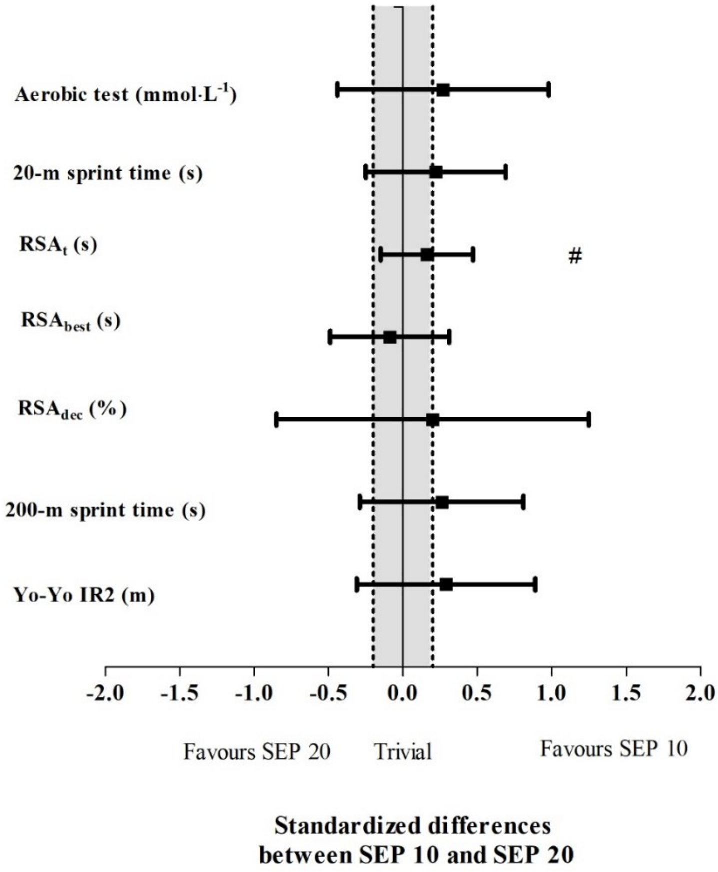


Figure 3.1: The effectiveness of SEP 10 compared with SEP 20 training to improve aerobic fitness test, 20-, and 200-m sprint time, total sprint time (RSAt), percentage decrement score (RSAdec) as well as the best sprint (RSAbest), and Yo-Yo IR2 performance. *Data are presented as the standardized difference (Cohen's d) ± 90% CI. # possibly.*

Training Monitoring

During the 2nd training session, significant differences were found between SEP 10 and SEP 20 for Total Number of accelerations > 4 m·s^{-2} (17 ± 2 and 11 ± 2, respectively), and for Total Number of decelerations > -4 m·s^{-2} (17 ± 3 and 11 ± 3, respectively) (P<0.05). The average metabolic power (P Met) during each exercise session was 37.6 ± 2.4 W·kg^{-1} in SEP 10 and 33.9 ± 1.7 W·kg^{-1} in SEP 20, with a significant difference between groups (P<0.05). No differences between groups were observed for Total time, Sprint Decrement, Sprint distance, Top speed, Total Number of accelerations of 3 to 4 m·s^{-2} and Total Number of decelerations of -3 to -4 m·s^{-2} **(Table 3.2)**.

During the last training session, significant differences were found between SEP 10 and SEP 20 for Total Number of accelerations > 4 $m \cdot s^{-2}$ (17± 3 and 10 ± 2, respectively), and for Total Number of decelerations > - 4 $m \cdot s^{-2}$ (17 ± 3 and 10 ± 2, respectively) ($P<0.05$). The Average P met reached per exercise session was 38 ± 3 $W \cdot kg^{-1}$ in SEP 10 and 36 ± 3 $W \cdot kg^{-1}$ in SEP 20, with a significant difference between groups ($P<0.05$). Only in SEP 10 were significant differences observed for pre to post changes in Total time 104.5 ± 4.0 s vs. 102.6 ± 3.0 s ($P<0.05$). No other significant pre to post differences were observed for either group.

Table 3.2: Training workload during the 2nd and the last training sessions for the different sprint endurance training groups. *Speed endurance production for 10 s (SEP 10); Speed endurance production for 20 s (SEP 20); Total time, percent of sprint decrement (Sprint dec), Total distance at a speed > 19.8 km·h^{-1} (Sprint distance); Top speed (m·s^{-1}); number of accelerations of 3 to 4 m·s^{-2} (Acc 3 to 4 m·s^{-2}); number of accelerations >4 m·s^{-2} (Acc > 4 m·s^{-2}); number of decelerations of -3 to -4 m·s^{-2} (Dec -3 to -4 m·s^{-2}); number of decelerations > -4 m·s^{-2} (Dec >- 4 m·s^{-2}); metabolic power average (P Met ave, W·kg^{-1}).*

	SEP 10					SEP 20				
	2nd	Last	Standardised differences (Coen's d ±90% CI)	Percent changes of worse/trivial/better performance	Qualitative inference	2nd	Last	Standardised differences (Coen's d ±90% CI)	Percent changes of worse/trivial/better performance	Qualitative inference
Total Time (s)	104.5 ± 4.0	102.6 ± 3.0*	- 0.44 ± 0.23	0/4/96	Very Likely	103.8 ± 2.2	102.9 ± 3.1	-0.38 ± 0.68	7/24/69	Unclear
Sprint dec (%)	4.9 ± 3.0	4.7 ± 2.0	0.02 ± 0.72	29/39/32	Unclear	4.9± 2.0	4.0 ± 2.0	-0.66 ± 0.7	3/11/86	Likely
Sprint distance (m)	436 ± 21	440 ± 48	0.07 ± 0.82	27/34/39	Unclear	456 ± 18	450 ± 30	-0.30 ± 0.50	5/31/64	Possibly
Top speed (m·s^{-1})	7.9 ± 0.4	7.8 ± 0.4	-0.14 ± 0.32	36/60/4	Possibly	8.0 ± 0.3	7.9 ± 0.5	-0.34 ± 0.44	72/26/3	Possibly
Acc 3 to 4 m·s^{-2}	3 ± 2	3 ± 3	-0.01 ± 0.12	1/98/1	Unclear	4 ± 3	4 ± 2	0.08 ± 0.68	23/40/37	Unclear
Acc > 4 m·s^{-2}	17 ± 2$^{\#}$	17 ± 3 $^{\$}$	0.10 ± 0.40	10/39/31	Unclear	11 ± 2$^{\#}$	10 ± 2$^{\$}$	-0.38 ± 0.61	70/24/6	Unclear
Dec -3 to -4 m·s^{-2}	3 ± 2	3 ± 3	-0.01 ± 0.12	1/98/1	Unclear	4 ± 3	4 ± 2	0.08 ± 0.68	23/40/37	Unclear
Dec > -4 m·s^{-2}	17 ± 2$^{\#}$	17 ± 3$^{\$}$	0.10 ± 0.40	10/59/31	Unclear	11 ± 3$^{\#}$	10 ± 2$^{\$}$	-0.08 ± 0.52	133/50/17	Unclear
P Met ave (W·kg^{-1})	37.6 ± 2.4 $^{\#}$	38.1 ± 3 $^{\$}$	0.14 ± 0.33	5/58/37	Possibly	33.9 ± 1.7 $^{\#}$	34.5 ± 2.8 $^{\$}$	0.26 ± 0.77	7/35/58	Unclear

Mean ± SD; * significant different Pre-Post (p<0.05); # significant difference between-groups in 2nd session (p<0.05); $ significant difference between-groups in the last session (p<0.05).

Between-group changes are presented in **Figure 3.2**. Changes in Total number of accelerations > 4 m·s^{-2} were possibly better in SEP 10 than those observed in SEP 20. Differences in the changes of all other features were unclear. Distances at different power output were also investigated during the two training protocols **(Figure 3.3)**, with no Within-group changes evident for either group. There were, however, significant between-group differences pre (Zones 25-30, 45-50, and > 50 W·kg^{-1}) and post (zones 40-45, 45-50 and > 50 W·kg^{-1}) training.

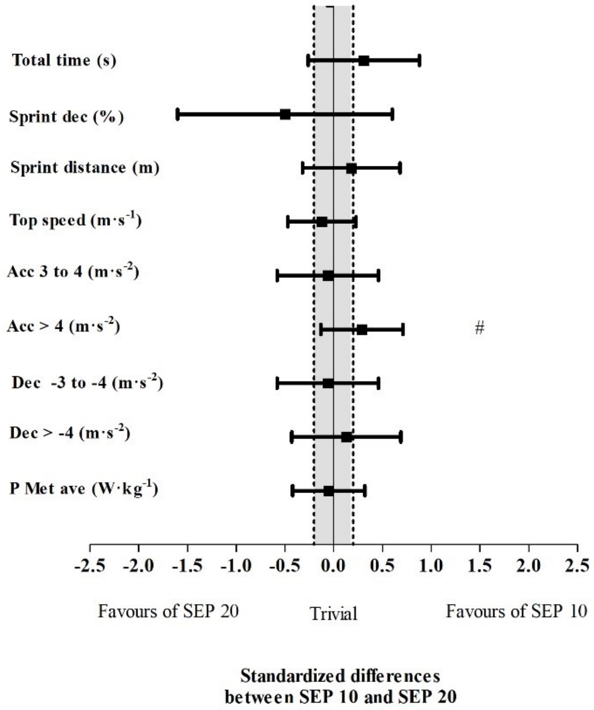


Figure 3.2: Effectiveness of Speed endurance for 10 s (SEP 10) compared with speed endurance for 20 s (SEP 20) training to improve workload after four weeks of training. *Total time, percent of sprint decrement (Sprint dec), Total distance at speeds > 19.8km·h^{-1} (Sprint distance); number of accelerations 3 to 4 m·s^{-2} (Acc 3 to 4 m·s^{-2}); number of accelerations > 4 m·s^{-2} (Acc > 4 m·s^{-2}); number of decelerations -3 to -4 m·s^{-2} (Dec -2 to -3 m·s^{-2}); number of decelerations > -4 m·s^{-2} (Dec >- 4 m·s^{-2}); metabolic power average (P Met ave W·kg^{-1}). Data are presented as standardized difference (Cohen's d) ± 90% CI; Unclear, # possibly.*

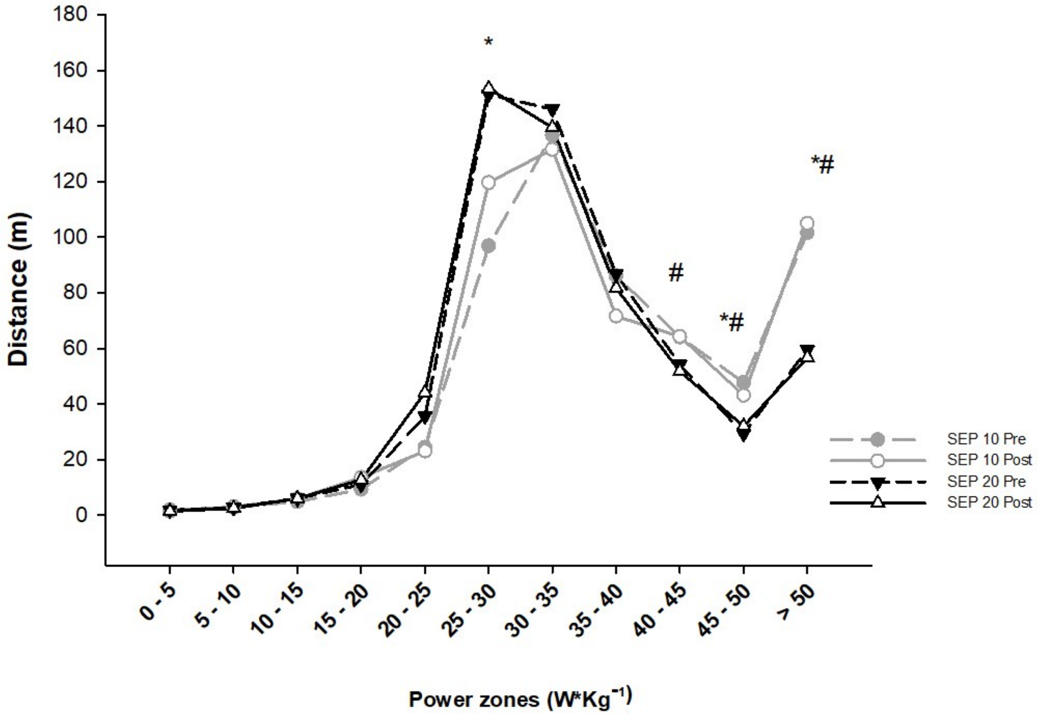


Figure 3.3: Distance completed in different power zones during both the second and last session for the two training groups. *Speed endurance production for 10 s (SEP 10) compared with speed endurance production for 20 s (SEP 20); *significant difference Pre-SEP10 vs Pre-SEP 20 (p<0.05); # significant difference Post SEP 10 vs Post-SEP 20 (p<0.05).*

Physiological responses

There were no significant time effects for changes in blood lactate concentration for either group from pre to post training **(Figure 3.4)**. There was, however, a significant sample time effect between-groups pre (S2-S4-S5 $p<0.05$), and post-training (S2-S3-S4-S5 $p<0.05$), with differences, observed within-times for blood lactate concentration in both groups: S1<S2<S2<S3<S4= S5 ($p<0.05$).

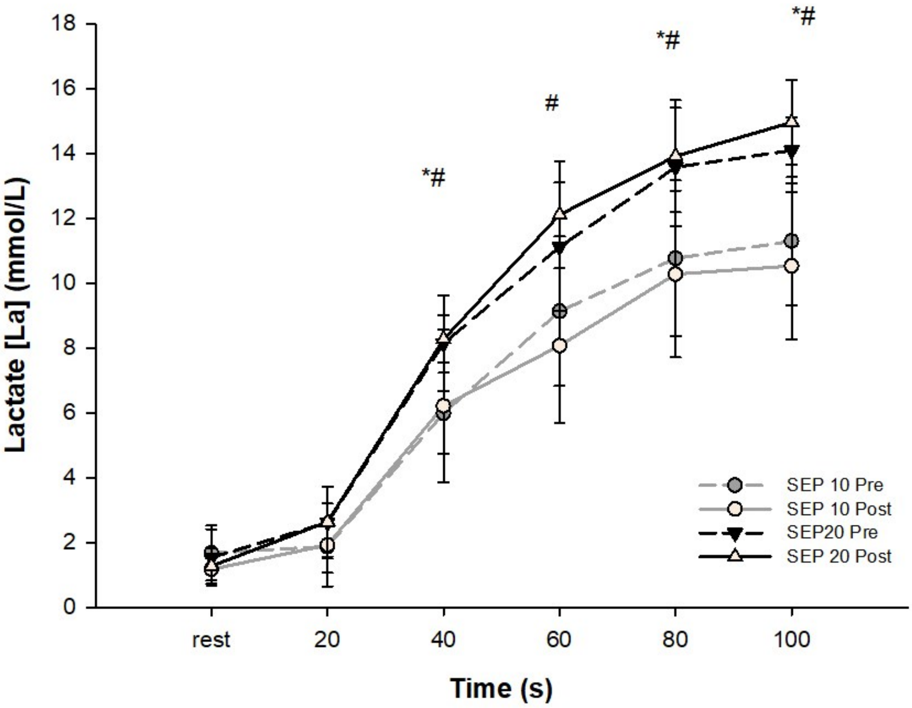


Figure 3.4: Blood lactate concentration during the second and last training session for either speed endurance production for 10 s (SEP 10) or speed endurance production for 20 s (SEP 20)*; *significant difference Pre-SEP10 vs Pre-SEP 20 (p<0.05); # significant difference Post SEP 10 vs Post-SEP 20 (p<0.05).*

Heart rate

Pre-training, there were significant between-group differences for HR_{mean} (82±4% vs 87±2% HR_{max} $p<0.05$) and time spent over 85% of HR_{max} (277±111 s vs 492±94 s $p < 0.001$), but not for HR_{peak} (96±3% vs 96±2% $p>0.05$) in SEP 20 versus SEP 10, respectively **(Figure 3.5)**. Post-training, there were no significant between-group differences for HR_{mean} (82±5% vs 86±5% HR_{max} $p= 0.16$), HR_{peak} (93±3% vs 96±3% $p= 0.05$), and time spent over 85% of HR_{max} (293 ± 119 s vs 422 ± 188 s $p > 0.05$) in SEP 20 versus SEP 10, respectively. There were also no significant between-group differences for the pre-to-post changes in any of the HR parameters.

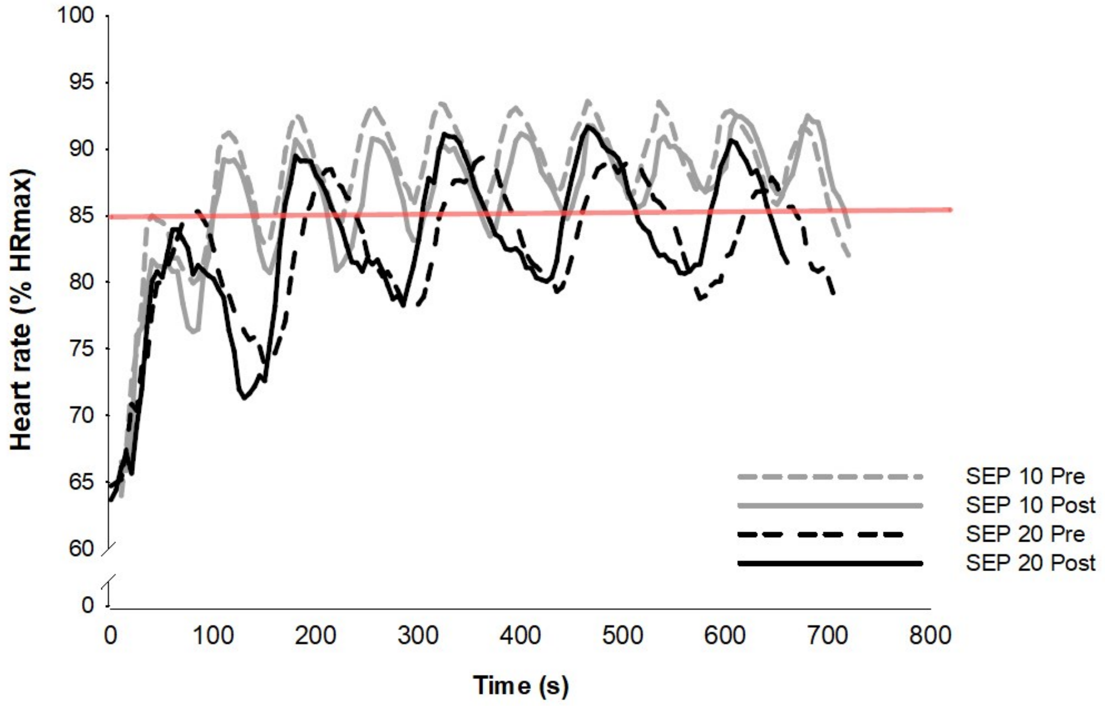


Figure 3.5: Heart rate during the second and last training session for the two different types of speed endurance training. *Speed endurance production for 10 s (SEP 10) and speed endurance production for 20 s (SEP 20)*

3.4 Discussion

The main findings show that SEP 10 was associated with a possibly greater effect on repeat-sprint total time compared with SEP 20. Additionally, the *likely* beneficial effect on distance covered during Yo-Yo IR2, suggests that repeated 10-second sprints provide a sufficient stimulus to enhance high-intensity intermittent exercise capacity. Furthermore, reducing the sprint duration from 20 to 10 seconds during speed-endurance training increased power output during exercise with a lower blood lactate concentration recorded at the end of the training protocol.

Following the four weeks of in-season training, there was a significant increase in RSA_t performance in both groups (1.5% and 1.1% in SEP 10 and SEP 20 $p<0.05$, respectively), with a *possibly* greater effect of SEP 10 compared with SEP 20. This possible between-groups difference is supported by the significantly higher power recorded during SEP 10 training. During the second and the last training sessions, there was a higher number of accelerations and decelerations ($> 4\ m \cdot s^2$) and a greater distance covered in high-intensity power zones, in SEP 10 versus SEP 20. This may have provided a greater mechanical stimulus and contributed to the greater improvement in RSA_t in SEP 10 [102].

Both SEP 10 and SEP 20 had a beneficial effect on 20-m sprint and RSA_{best} performance, which suggests that both types of training can improve sprint performance. This similar improvement in performance occurred despite SEP 10 and SEP 20 being associated with distinct physiological responses (e.g., Heart rate, blood lactate concentration), as well as distinct power at acceleration profile (described above). It seems that any small differences between groups only became apparent when the performance of multiple sprints was summed (i.e., RSA_t). The absence of significant differences between groups may be related to the recruitment of young male soccer players in the present study.

The Aerobic level measured with aerobic fitness test was maintained during the training period. It has been suggested that an optimal stimulus to elicit both maximal cardiovascular and aerobic peripheral adaptations is to spend more than 10 to 15 min per session above 85 % of HR_{max} [38]. The absence of improvements in our aerobic fitness test is consistent with the low amount of time (< 8 min) spent above 85% HR_{max} for both groups. This indicates that repeated all-out efforts with long-duration recovery (W: R 1:6) do not provide a sufficient stimulus to induce changes in aerobic fitness. The absence of improvement in our aerobic fitness test is consistent with studies in trained participants reporting that speed-endurance training-induced primarily peripheral remodelling, such as restructure of muscle architecture [91, 93], changes in membrane transport proteins involved in regulating muscle pH [93, 96], and preservation of cell excitability [37, 93, 96] but not improvements in VO_{2max} [37, 91, 93, 96]. Despite no changes in our aerobic fitness test, there was a significant increase in high-intensity intermittent capacity as indicated by distance covered during the Yo-Yo IR2 test (10% and 16% in SEP 20 and SEP10 $p<0.05$, respectively). This improvement is in agreement with the results of several studies that have investigated the effects of speed-endurance training on fatigue resistance during high-intensity exercise [33] but are lower than previously observed in studies involving recreational soccer players [40]. This suggests that speed-endurance training is a valid strategy to improves high-intensity intermittent capacity in soccer players.

The lower blood lactate concentration, at the end of the exercise, during SEP 10 compared to SEP 20 indicates that more extensive repeated all-out efforts are strongly related to anaerobic production. This is in accord with previous studies that have shown a high-level of blood and muscle lactate concentration at the end of exercise characterized by long efforts [36, 98]. Surprisingly, there were no significant differences between groups for 200-m performance, although the differences observed in blood lactate concentration can suggest a different amount of lactic anaerobic contribution between groups.

In conclusion, this study highlights that a short period of speed-endurance training improves aspects of high-intensity exercises performance and repeated-sprint ability. Furthermore, the high metabolic power and the high number of accelerations > 3 $m \cdot s^{-2}$ recorded, despite a lower amount of lactate accumulation, suggest that SEP 10 is an excellent strategy to improve soccer-related physical performance. The large number of accelerations and decelerations, performed at a high intensity, in SEP 10 versus SEP 20, suggest that this type of training may also be of greater benefit to improve the ability to accelerate and decelerate. Nonetheless, this study was characterized by a series of a limitation such as short duration period (4 weeks), low number of participants involved and absence of control group. Therefore, further research is required to investigate if similar results are observed following larger duration of training in well-trained soccer players.

3.5 Practical Applications

From a practical point of view, understanding the characteristics of a training stimulus and its effects on the performance, allows coaches and staff to optimize the training prescription. Specifically, the manipulation of sprint duration can modify the mechanical and physiological output. This information can be useful to individualize training prescription based on role and players characteristics. Furthermore, the increase in neuromuscular stimulus, due to the high-power output recorded after SEP 10, suggests that in a short-term period a reduction in sprint duration generates positive adaptation on soccer-related physical performance.

4° CHAPTER – Study 3

THE PHYSIOLOGICAL DIFFERENCE OF SPEED ENDURANCE AND REPEAT SPRINT TRAINING IN MODERATELY-TRAINED SOCCER PLAYERS

4.1 Introduction:

Understanding the training-induced effects is important to develop training programs in teams sport, especially in soccer where the complexity of physical demands and the difference between role position requires a careful choice of the training stimulus [1, 2, 12]. In soccer, a widespread training practice is focused on the performance enhancement throughout the maximization of the high-power output or the minimization of the performance deterioration [6, 32]. The purpose is to “isolate” training contents targeting specifically neural or metabolic factors. For example, strength and power training was used to improve maximal performance qualities (i.e., jumping, sprint time, change of direction, acceleration), while endurance-based training provided a stimulus for optimizing oxidative metabolism, rating of phosphocreatine recovery, and hydrogen-ion (H^+) buffering, [1, 6, 12]. Although this approach is considered by many authors to be more effective [6, 32], recently, different “mixed” training approaches (targeting both neuromuscular and metabolic systems simultaneously) have been proposed with team-sport athletes [33, 34].

Repeated sprint exercise training (sprints from 3 to 7 s, interspersed with recovery periods generally lasting less than 60 s; RSE) and sprint endurance training (multiple prolonged “all-out” bouts ≤ 40 s separated by comparatively long resting periods; SET), are the more investigated mixed training approach. [6, 92]. These forms of maximal exercise require athletes to achieve peak power output subsequently and maintain it throughout the sprint duration. This maximal-mechanical demand requires a high energy production that is produced primarily via anaerobic pathway, with an increase of the aerobic contribution in the last part of the sprint, during recovery, and during the subsequent sprint [23, 26]. Thus, within the same training, it is possible to target both neuromuscular and metabolic factors simultaneously. However, due to the different variables used (i.e., sprint duration, recovery time and number of sprints), a distinction between the two methods should be made.

During RSE the short-sprint duration (3 to 7 seconds) allows athletes to achieve a high-power output during the first sprints, with a high neuromuscular demanding. On the other hand, the short-recovery time available (< 60 s) allows only a partial restoration of adenosine triphosphate (ATP), and phosphocreatine (PCr) stores at the onset of each subsequent sprint, contributing to a reduction in performance and an increasing sprint decrement [26, 29]. On the contrary, during SET the longer sprint duration, induces a high anaerobic glycolytic and aerobic system contribution, that may induce a higher reduction in power production already during the first sprint [25]. Nonetheless, the longer duration recovery (60 to 300 s) allows athletes to achieve a high level of PCr resynthesis, that results in the maintenance of performance with a reduction of sprint decrement following exercise [33]. Thus, it seems that the short-time duration and short-time recovery in RSE, as well as longer sprint-duration and longer recovery time in SET, may differently tax neuromuscular and metabolic pattern, generating different physical adaptation. However, no studies have directly compared the physiological and mechanical profile of RSE, and SET and the studies available are not matched for total sprint distance and/or total time of work. In contrast with this hypothesis, several studies observed a similarly broad spectrum of soccer-related performance adaptation induced by these forms of training [33, 34, 38, 39]. For example, Ferrari Bravo et al. (2008) and Mohr et al. (2016) reported a similar improvement in repeat sprint ability (~2%) after RSE and SET. Likewise, Iaia et al. (2015) and Iaia et al. (2017) reported similar improvement in Yo-Yo intermittent recovery test level 2 after four weeks of RSE and SET (when data are matched for work recovery ratio). However, repeated sprint ability and high-intensity capacity are complex fitness component, and the training stimuli induced with RSE, and SET may target different component (e.g., RSA total time or RSA decrement) generating similar adaptation [6]. For these reasons, further research is needed to directly compare the physiological and mechanical response of these forms of training during and at the end of the exercise and clarify the specific physiological component target by these form of training.

Therefore, the present study aimed to compare the physiological response and mechanical profile during RSE and SET to understand the training-induced effects on moderately-trained soccer players. By measuring the responses during repeated sprints (three series of six 5-second sprints with 20 seconds of recovery between sprints and 3 minutes between series) and speed endurance training (six 15-second sprints with 90 seconds of recovery between sprints) we aim to understand the peculiar features of those training to better prescribe training sessions in moderately-trained soccer playes.

4.2 Methods:

Participants

Fourteen soccer players (age 21 ± 2 y., height 181± 5.5 cm, body mass 74 ± 8.3 kg) belonging to the same team and moderately-trained (used to carry out 3 workouts plus the game a week) were involved in this study. Participants had a minimum of 9 y. of experience in soccer. After medical screening to rule out any conditions that may have precluded their participation (e.g., cardiovascular or musculoskeletal problems), the participants were fully informed of any possible risks and discomforts associated with the experimental procedures before giving their written informed consent. The local ethics committee also approved the study. After an initial performance test, players were matched on their fitness level and randomly allocated to either speed endurance training (SET; n = 7) or repeat sprint exercise training (RSE; n = 7) groups. The randomization process was based on the value achieved during each test. Each test attributed a score from 1 to 14 AU depending on the level of performance achieved. The participant achieves the best performance received 14 points the worst 1. the sum of the score determined the final score. on the basis of these values the subjects were allocated in the two groups.

Study design

In order to evaluate the physiological responses during two different exercise session, a parallel experimental design was used. This study was conducted during the first part of the competitive season (Oct to Dec) and consisted of one week of testing session followed by a two-weeks familiarization period. During the experimental training session, the player' external load was assessed with GPS technology, while heart-rate (HR), blood lactate concentration (La^-), and rating of perceived exertion (RPE) were used to characterize physiological responses and players' internal load. Before the intervention, players were performing three training sessions per week (i.e., Tuesday, Wednesday, Friday) and a full-length game (Sunday). Warm up activities were performed before the daily training and consisted of individual preparation and injury-prevention exercises (FIFA 11+ protocol) characterized by a gradual increase in intensity. On Tuesdays, a low-intensity technical/tactical session of 40 to 60 minutes was performed and, during the physical conditioning component, soccer players were divided into different groups, based on match training load, and performed active recovery strategies or high-intensity interval training. Wednesday training sessions were characterized by strength training, technical/tactical drills, and small-sided games. On Fridays, training sessions consisting of agility exercise with changes of direction and quick-feet drills. During the two week of familiarization period, the habitual conditional training (Tuesday and Friday) was replaced by SET or RSE, whereas the rest of the weekly training routine was kept the same as before the study.

The SET protocol consisted of 6 repetitions of ~15-seconds all-out bouts (shuttle runs of 3 x 30 m) interspersed with 90 s of passive recovery (work: rest ratio 1:6), while RSE was characterized by three series with 6 x ~5-second all-out repetitions (30-m straight-line or shuttle runs of 2 x 15 m) followed by 20 s of passive recovery between repetitions and 3 minutes of passive between series (work: rest ratio 1:4). Thus, total distance and, number of changes of direction were equal for SET with RSE and were increased during the familiarization period. Also, session rating of perceived exertion (RPE) was collected ~20 min after every session using the Borg CR-10 scale, and RPE-based training load was calculated as training duration x RPE score [81]. All SET and RSE training sessions took place on artificial grass (i.e. 2nd generation). No other physical exercise was conducted aside from that prescribed by the football club. Furthermore, in order to minimize any potential interference of external variables, the players maintained their standard lifestyle and regular food intake in the weeks before and during the experiment. During the experimental session blood lactate samples, from the earlobe, were collected after selected bouts (1-6-12-18 in RSE and 1-2-4-6 in SEP). Sprint time was also recorded during the evaluation by the use of portable photoelectric cells (Witty, Microgate, Bolzano, Italy) and player' external load was assessed via a GPS system (PLAYERTEK, Dundalk, Co Louth, Ireland).

Data GPS collection

The player' physical activity during RSE and SET was monitored using a portable non-differential 10-Hz global position system (GPS) integrated with 400-Hz Tri-Axial Accelerometer and 10-Hz Tri-Axial magnetometers (PLAYERTEK, Dundalk, Co Louth, Ireland), and included the activities from the first until the last sprint (3 minutes of recovery between series in the RSE group were excluded from the GPS analysis). The devices were placed between the players' scapulae through a tight vest and were activated 15 minutes before the data collection, by the manufacturer's instructions, to optimize the acquisition of satellite signals [73]. In order to avoid inter-unit error, players wore the same GPS device for each training session [74]. The physical demands of each training session for each player were evaluated through the assessment of sprint distance (> 19.8 $km \cdot h^{-1}$), Top speed ($m \cdot s^{-1}$), number of accelerations and decelerations above 3 $m \cdot s^{-2}$, and with the estimation of the energy cost (EC; in $J \cdot kg^{-1} \cdot m^{-1}$) and the associated metabolic power (P met; in $W \cdot kg^{-1}$) that were calculated during each drill, with the equations proposed by Di Prampero et al. [103] and then modified by Osgnach et al. [9]. Furthermore, time spent at different metabolic power zones was also assessed (5-10, 10-15, 15-20, 20-25, 25-30, 30-35, 35-40, 40-45, 45-50, >50 $W \cdot kg^{-1}$).

Heart rate measurement:

The maximal heart rate (HR_{max}) of the players was estimate during the Yo-Yo IR2. Throughout a heart rate monitor (RS400 polar, Finland) was recorded the HR peak, and subsequently calculated the heart rate thresholds (95-90-85-80% of the HR_{max}).

Performance test

All players were already familiarised with all testing procedures. On the days of testing, participants reported to the pitch 2 h 30 min after having consumed a light meal. Participants also refrained from strenuous physical activity and abstained from alcohol and caffeine consumption, 24 h before testing. To reduce the possible effect of diet-induced changes on muscle metabolism and subsequent exercise performance, two days before any experimental testing the participants were required to follow a nutritional strategy designed to ensure carbohydrate intake of the ~60% of total energy intake.

Aerobic Fitness Test

Aerobic Fitness Test was performed on the artificial ground (2nd generation) and consisted of 6 min at a constant running speed of 13.5 $km \cdot h^{-1}$. This test known as “Mognoni test” is a threshold test that is utilised to obtain indirect information regarding the aerobic fitness of the players. Audio signals controlled the test. Capillary blood samples were taken from the earlobe at rest and immediately after the test. Blood lactate concentration [La$^-$] was analyzed using a portable lactate analyzer (Lactate Plus, Nova Biomedical, Waltham, MA, USA).

20- m sprint tests

The short-sprint performance was evaluated over a 20-m distance on the artificial ground (2nd generation). Time was recorded using photoelectric cells (Witty, Microgate, Bolzano, Italy). Players started the sprint from a standing position with the front foot placed 10 cm before the first timing gate. Only the best performance over three trials was considered. Each 20-m sprint was separated by 3 min of passive recovery.

RSA test

The RSA test was performed on artificial ground (2nd generation) and consisted of five repetitions of 30-m all-out sprints interspersed with 25 s of passive recovery. Time was measured with photoelectric cells (Witty, Microgate, Bolzano, Italy). Total sprint time (RSA$_t$) for all five sprints (S_1-S_2-S_3-S_4-S_5 – time in seconds –) was determined. Also, in order to quantify fatigue during the RSA test, the percentage decrement score (RSA$_{dec}$) was calculated as follows [78]:

$$RSAdec = \left[\frac{S_1 + S_2 + S_3 \cdots + S_{final}}{S_{best} \times number\ of\ sprint} - 1\right] \times 100$$

200-m sprint test

A 200-m all-out run was performed. Time recordings were obtained by photoelectric cells as previously described for the short sprint tests. Capillary blood samples were taken from the earlobe at rest and immediately after the 200-m sprint test. Blood lactate concentration [La$^-$] was analyzed using a portable lactate analyzer (Lactate Plus, Nova Biomedical, Waltham, MA, USA).

The Yo-Yo Intermittent Recovery Test level 2

The Yo-Yo Intermittent Recovery Test level 2 was performed on natural turf, after 15-minutes of standardized warm-up. The test consists of 2 x 20-m shuttle runs at increasing speeds, interspersed with 10 s of active recovery, controlled by audio signals. The test was stopped when the subject was no longer able to maintain the required speed and the distance achieved was recorded [79].

Statistical Analyses

The normal distribution of each variable was examined with the Shapiro-Wilk test. One-way ANOVA analyzed data with repeated measures to detect potential interactions. The level of statistical significance was set for all analyses at $p < 0.05$. In addition to null-hypothesis testing approach, magnitude-based inference approach was also adopted to focus on the practical relevance [80]. For between-group changes, the chances that the true mean changes were beneficial (i.e., greater than the smallest worthwhile change, SWC [0.2 multiplied by the between-subject standard deviation]), unclear or harmful were considered. The corresponding quantitative chances of beneficial, unclear of harmful changes were evaluated as follows: 25-75%, *possibly*; 75-95%, *likely*; 95-99%, *very likely*; and >99%, *almost certainly*. If the chance of obtaining greater and poorer differences was both >5%, the true difference was assessed as *unclear*. To perform each calculation and interpretation related to the magnitude-based inference approach, customized spreadsheets, available at www.sportsci.org/index.html, were utilized. Data are presented as means ± SD, whereas relative changes are presented as means ±90% confidence intervals.

4.3 Results

Baseline physiological parameters were not different between the two groups **(Table 4.1)**. The comparison of the performance during exercise SET and RSE showed a significant difference for Sprint Total time (94.5 ± 3.2 s and 102.0 ± 2.6 s, respectively), Total Number of accelerations > 3 $m \cdot s^{-2}$ (16 ± 4 and 26 ± 4, respectively), and for Total Number of decelerations > -3 $m \cdot s^{-2}$ (14 ± 3 and 18 ± 4, respectively) ($p<0.01$). While, no differences between SEP and RSE were observed for Sprint decrement (25.7 ± 3% and 25.1 ± 0.8%, respectively) or Top speed (7.8 ± 0.5 $m \cdot s^{-1}$ and 7.5 ± 0.6 $m \cdot s^{-1}$, respectively) **(Table 4.2).**

Table 4.1. Baseline characteristics of the participants in the Speed endurance training (SET) and repeated sprint exercise training (RSE)groups; data are mean± SD

Measurements	SET group (n=7)	RSE group (n=7)
Age (y)	20.7 ± 2.5	20.8 ± 1.5
Mass (kg)	69.7 ± 6.3	76.7 ± 8.3
Height (cm)	179.7 ± 4.4	182.5 ± 6.4
Aerobic Test (La^-)	4.2 ± 2	4.6 ± 1.6
20-m sprint time (s)	3.08 ± 0.11	3.03 ± 0.10
RSA_{time}	22.61 ± 0.71	22.68 ± 0.65
RSA_{DEC} (%)	3.7 ± 1.4	3.6 ± 1.7
200-m sprint time (s)	27.5 ± 1.5	27.7 ± 1.7
200-m lactate (La^-)	7.4 ± 1.6	7.5 ± 2.3
Yo -Yo IR2 (m)	634± 147	651 ± 180

Total sprint time (RSA_{time}), percentage decrement score (RSA_{dec}), best sprint (RSA_{best}), Yo-Yo intermittent recovery test level 2 (Yo-YO IR2)

Table 4.2. Training workload during training sessions for the speed endurance training (SET) and repeat sprint exercise training (RSE)groups. Data are means ± SD;

Measurements	***SET group*** ***(n=7)***	***RSE group*** ***(n=7)***	**Standardised differences (Coen's d ±90% CI)**	**Qualitative inference**
Total sprint time (s)	94.4 ± 3.2	102.0 ± 2.6 *	2.40 ± 0.89	Very likely
Decrement (%)	25.7 ± 2.6	25.1 ± 0.8	-0.17 ± 0.71	unclear
Sprint distance >19.8 ($km \cdot h^{-1}$)	316 ± 109	226 ± 59	-0.65 ± 0.98	unclear
P Met ave ($W \cdot kg^{-1}$)	8.0 ± 2.0	11.3 ± 1.2 *	2.64 ± 0.97	Very likely
Top speed ($m \cdot s^{-1}$)	7.8 ± 0.5	7.5 ± 0.6	-0.54 ± 0.98	unclear
Acc > 3 $m \cdot s^{-2}$	16 ± 4	26 ± 4*	1.70 ± 0.99	Very likely
Dec >-3 $m \cdot s^{-2}$	14 ± 3	18 ± 4*	1.23 ± 0.97	Very likely

* significant different between-groups ($p<0.05$).Total time, percent of sprint decrement (Sprint dec), Total distance at speed > 19.8 $Km \cdot h^{-}$ [1] (Sprint distance > 19.8 $Km \cdot h^{-1}$); Metabolic power average (P Met ave $W \cdot kg^{-1}$); Top speed ($m \cdot s^{-1}$); number of acceleration >3 $m \cdot s^{-2}$ (Acc > 3 $m \cdot s^{-2}$); number of deceleration > -3 $m \cdot s^{-2}$ (Dec > -3 $m \cdot s^{-2}$).

The analysis of total distance at various intensities (Power Zones) showed significant differences between groups for total distance completed in Zones 10-15, 15-20, and 20-25 $W \cdot kg^{-1}$ ($p<0.05$), while no differences were recorded at other intensity (**Figure 4.1**)

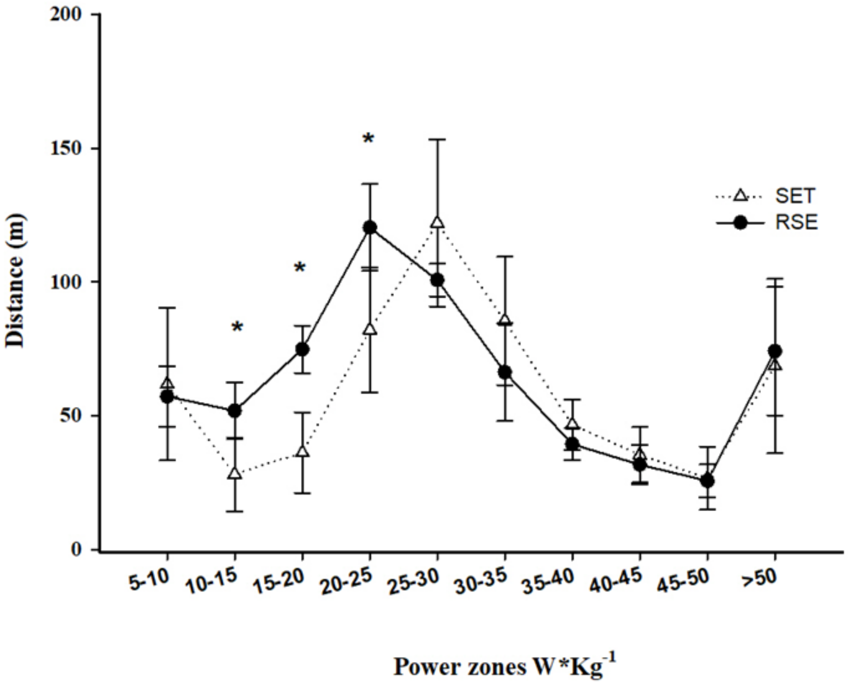


Figure 4.1: Distance completed in different power zones for the two training groups. **significant difference SET vs RSE (p<0.05);*

Blood lactate concentration increased from 1.5 ± 0.2 to 11.1 ± 3.2 mmol·L^{-1} in SET and from 1.8 ± 0.8 to 7.2 ± 2.8 mmol·L^{-1} in RSE, with significant differences between groups after 60 s (9.4 ± 2.1 and 7.1 ± 2 mmol·L^{-1} in SET and RSE, respectively p<0.05) and 90 s (11.1 ± 3.2 and 7.2 ± 2.8 mmol·L^{-1} in SET and RSE, respectively p<0.01) **(Figure 4.2).**

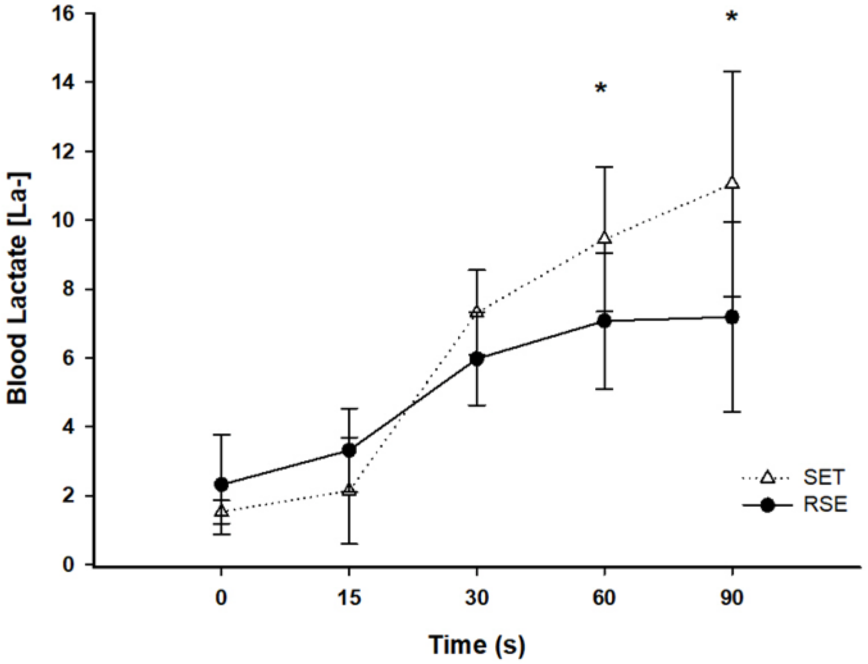


Figure 4.2: Blood lactate concentration during a training session for both the speed endurance training (SET) and repeat sprint exercise training (RSE) groups*; *significant difference SET and. RSE ($p<0.05$).*

The quantification of the time spent at different heart rate thresholds showed significant between-group differences for time spent above 90% of HR_{max} (182 ± 51 s in RSE and 95±45 s in SET ($p<0.05$), with no differences for time spent between 80 and 90% of HR_{max}. The HR_{mean} and HR_{peak} reached during exercise were similar in both groups **(Table 4.3).** An example of the heart rate during RSE and SET training are presented in **Figure 4.3.**

Table 4.3: Heart rate during exercise for the SET and RSE group. *Mean heart rate and peak heart rate are expressed as a percentage of maximal heart rate (HRpeak %HRmax); Also shown is Time spent between 80 to 85% maximal heart rate (Time HR 80-85%); Time between 85 to 90% maximal heart rate (Time HR 85-90%) and above 90% maximal heart rate (Time HR > 90%); speed endurance training (SET); repeat sprint exercise training (RSE).*

Measurements	SET group (n=5)	RSE group (n=5)
HR_{mean} $\%HR_{max}$	81 ± 4	79 ± 3
HR_{peak} $\%HR_{max}$	94 ± 1	95 ± 3
Time HR 80-85 % (s)	83 ± 33	77 ± 45
Time HR 85-90 % (s)	109 ± 31	147 ± 36
Time HR > 90% (s)	95 ± 45	182 ± 51*

*means ± SD; * significant difference (p<0.05)*

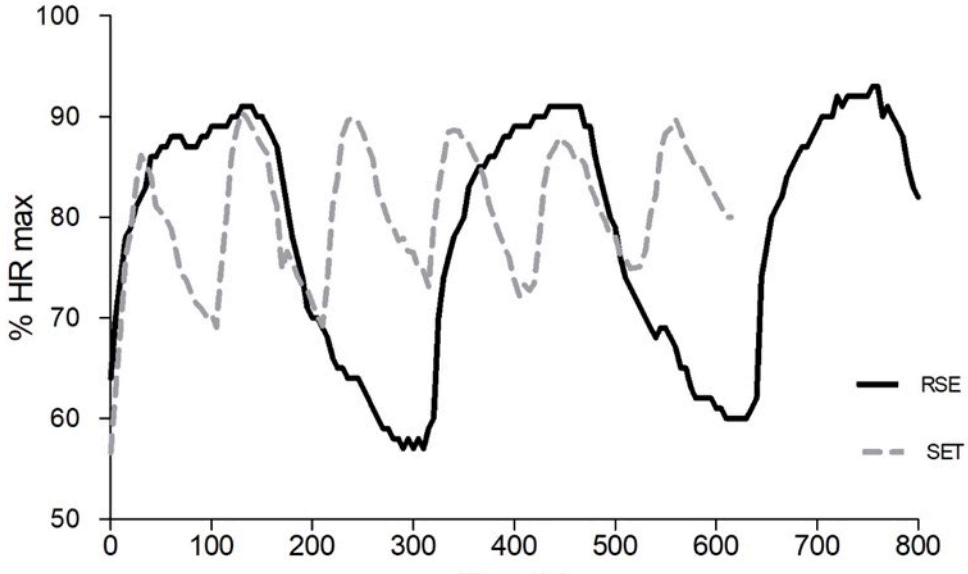


Figure 4.3: Heart rate during a training session for the Speed endurance training (SET) and repeat sprint exercise training (RSE). The Heart rate reported in this figure represents the average Heart rate achieved by the players in each group.

4.4 Discussion

The main result of this study shows the different physiological and mechanical profile of SET and RSE in moderately-trained soccer players. Specifically, SET elicited to higher average speed and higher blood lactate concentration, while RSE involved a higher mechanical load and heart rate response.

The mechanical profiles of the two training approaches showed a higher number of accelerations and decelerations ($> \pm 3\ m\cdot s^{-2}$), and a higher distance covered between 10 and 25 $W\cdot kg^{-1}$ in RSE compared to SET. This greater mechanical demand during RSE suggests that short sprint duration stimulates the acceleration and deceleration phases, increasing the metabolic power. In fact, despite both protocols were matched for number of changes of direction and total distance, the different manipulation of sprint duration and recovery have modified the characteristic of the mechanical demand. This is also confirmed by the analysis of the average speeds obtained during the trainings, with SET performed at higher speeds compared to RSE ($20.6 \pm 1\ km\cdot h^{-1}$ and $18.9 \pm 1.3\ km\cdot h^{-1}$). Thus, it could be concluded that SEP and RSE differently involve the mechanical load of the muscles during the maximal efforts. Therefore, changing in sprint and recovery time durations may have also a role in the mechanical load of the muscles involved.

The HR profile showed a greater time spent above 90% of HR_{max} in RSE compared to SET. A possible explanation can be provided by the time (20 s) spent to recover during RSE, which may be not enough to reduce HR at the onset of each subsequent sprint, involving a higher HR_{mean} at the end of each series. Conversely, the time (90 s) spent to recover during SET was sufficient to reduces HR after exercise, decreasing the total time spent above 90% of HR_{max}. Additionally, the different metabolic power recorded in RSE compare to SEP might have affects the heart rate response. In fact, the high energetic cost of acceleration and deceleration, especially if performed at high intensity, may have contribute to modify the heart rate response. However, despite these differences would indicate a greater aerobic stimulus (leading to greater aerobic power) by RSE, the similar HR_{peak} and a similar time spent between 80 and 90% of HR_{max} of SET may be considered sufficient to generate improvement in aerobic power in both groups [38]. Accordingly, previous studies have reported an increase of ~4.8% of $\dot{V}o_{2max,}$ after a period of RSE and SET [33-35, 92]. While, recent studies have been reported that SET and RSE upregulate the content of a series of mitochondrial proteins responsible for an increase of oxidative capacity in human skeletal muscle [104, 105].

The analysis of blood lactate concentration showed a different anaerobic contribution between groups, with a higher blood lactate concentration following SET compared with RSE. This difference may be attributed to the lower lactate production during short sprints, due to a delay in the maximal rate of ATP resynthesis from glycolysis [25]. Indeed, to achieve the maximal rate of resynthesis of ATP from glycolysis the sprint duration should exceed ~5 seconds [25]. However, this is not supported by the absence of significant difference in lactate concentration during the first 30 seconds of exercise recorded in this study. A possible explanation might be attributed to the different timing in blood lactate measurement. Indeed, despite the samples were taken after the same time of work, the presence of recovery time between bouts in RSE may have facilitated the accumulation of lactate in the blood in the first stages of exercise. Therefore, further research involving more accurate physiological measurement are needed to better understand the differences in anaerobic contribution during short and long repeated sprint exercises.

In conclusion, the assessment of SEP and RSE, respectively characterized by long sprint duration and long recovery and short sprint duration, showed a different physiological response and mechanical profile between groups. The measurement of heart rate and blood lactate concentration are not enough to suggest possibly difference in physical adaptation. Conversely, the assessment of the mechanical profile provides useful information about the different nature of the two-training stimulus and the external load induced by SET and RSE.

Limitation of the study

In addition to the low number of participants involved in the present study, it could be argued that we used a different work recovery ratio (W: R) between the two experimental groups. However, when different training methods are compared, the absolute sprint duration and the absolute recovery time already affect metabolic and mechanical profile [23]. For this reason, we adopted two W: R typically used in football environment [92, 106], and used equal total distance and number of changes of direction in both groups.

5° CHAPTER – Conclusions

CONCLUSIONS, PRACTICAL APPLICATIONS & PROSPECTIVES

In accordance with the results found in this thesis, it is possible to assert that the manipulation of the tapering workload and the training stimuli directly affect the physical performance. The decrease of the weekly workload before the match allows reducing the accumulated fatigue induced by previous matches and high-load training sessions. In particular, it was suggested that a training load reduction *per se* is insufficient to improve physical preparedness, and the optimization of the workload decrement is required for a positive effect. Thus, it appears clear that careful monitoring of the weekly workload and accumulated fatigue is required, in order to help soccer players to maintain the higher performance throughout the soccer season. In any case, future works are scheduled with the purpose of quantifying the effect of workload on fatigue development and individualize the tapering based on players' fitness level and period of the season.

Moreover, as shown in the second part of this thesis, it seems also possible to optimize players preparedness throughout the enhancement of soccer-related-physical performance. Understanding the physiological and physical stimulus induced by different training-variables manipulation is essential to prescribe the training. For example, the data of the second and third study of this thesis suggested that the manipulation of sprint duration and recovery ratio can generate different physical performance adaptation, able to affect soccer-related performance differently. In this way, soccer clubs may schedule daily training programs based on players' characteristics in order to individualize the training stimulus. However, physical training and specific physical drills are the tip of the iceberg of soccer physical preparation. For these reasons, future studies are needed to compare and classify other forms of training, containing tactical and technical skills, in order to better understand the impact of these forms of training on soccer-related performance.

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Index of abbraviation

CMJ: countermovement jump

GPS: global position system

HIT: high-intensity-interval-training

HR: heart rate

HRmax: heart rate max

HRpeak: heart rate peak achieves during exercise

HRmean: heart rate average during exercise

%HRmax: percentage of maximal heart rate

RSA: repeat sprint ability

RSAt: total time performed during repeated sprint test

RSAdec: sprint decrement during repeated sprint test

RSE: repeat sprint exercise

RST: repeat sprint training

SEM speed endurance maintenance

SEP: speed endurance production

SET: speed endurance training

SIT: sprint interval training

ST: sprint training

Yo-Yo IR1: Yo-Yo intermittent recovery test level 1

Yo-Yo IR2: Yo-Yo intermittent recovery test level 2

V̇o2max: maximal oxygen uptake