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Heart rate during intermittent in-line and shuttle effort

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Abstract:
The aim of this study was to explore the heart rate response during high-intensity intermittent exercise, highlighting the impact of changes in direction during shuttle exercise. Two protocols were compared: one in line and one in shuttle with different intensities. This research is of major interest for quantifying intermittent training loads. The experimental study was carried out on a sample of 10 male S.T.P.A.S students at the Sétif 2 University. The results of the statistical analysis revealed that intermittent shuttle training influences athletes' performance differently from line training, and that changes in direction led to a significant increase in mean heart rate.
Key words: Line intermittent; Shuttle intermittent; Heart rate

الملخص:

هدفت هذه الدراسة من جهة، إلى معرفة استجابة نبض القلب للجهد المتناوب 10ثا- 20ثا و15ثا- 30ثا، ، و من جهة أخرى، مقارنة أثر الجهد المتناوب في نفس الاتجاه، و بتغيير الاتجاه، و كذلك مقارنة أثر عدد مختلف من تغير الاتجاه خلال الجهد المتناوب ، و لذلك، قمنا بإجراء دراستنا التجريبية على عينة تكونت من مجموعتين تجريبيتين ، و كل مجموعة تكونت بدورها من 10 لاعبين، من جنس ذكر، من قسم ع.ت.ن.ب.ر، جامعة سطيف 2. بعد المعالجة الإحصائية لمختف هذه النتائج، اتضح لنا وجود فروق ذات دلالة معنوية بين أثر الجهد المتناوب في نفس الاتجاه وبتغيير الاتجاه
الكلمات المفتاحية: الجهد المتناوب في نفس الاتجاه؛ الجهد المتناوب القصير بتغيير الاتجاه؛ معدل نبض القلب.

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1.Introduction

Heart rate represents an important parameter for quantifying load by measuring intensity, and monitoring functional adaptation to training loads (Nhaoua A, 2016). However, HR measurements are determined by multiple influential factors, such as environment (Noise, light, temperature), physiological (Cardiac morphology, plasma volume, autonomic activity), pathological (mood, emotions, stress) and non-modifiable factors (age, gender, ethnicity), as well as lifestyle (fitness, sleep, medication, tobacco, alcohol) and physical activity determinants (duration, modality, economy, body position) (Sandercock G.R.H and al., 2005; Buchheit M, 2014; Fatisson J and al., 2016; Sessa and al., 2018). Nevertheless, in competitive sports, the influence of training plays a predominant role in changes in autonomic nervous system status and, therefore, HR measurements could represent the athlete's training status (Lamberts R.P and al., 2010; Buchheit M, 2014 in Sedeaud A and al., 2018).

Heart rate is mainly regulated by the sympathetic and parasympathetic branches of the autonomic nervous system via antagonistic control; the orthosympathetic branch acts as a gas pedal on the sinus node located in the right atrium, via the release of neurotransmitters called catecholamines. The parasympathetic branch acts on the sinus node as a cardio-moderator, via the release of acetylcholine. At this level, aerobic physical activity is highly influential. It increases parasympathetic activity at rest, resulting in bradycardia (Moustaghfir A and al. 2002). We can also note that it enables the vagal brake to be lifted more rapidly, and the appearance of less cardiac drift during rectangular exercise, through overexpression of the orthosympathetic branch. When exercise is stopped, or during a recovery phase between two sequences, the heart rate gradually falls back to its resting value. This fall occurs in two distinct phases. The rapid phase during the first minute post-exercise, leads to a rapid decrease to near-rest values. The return to resting values then takes place at a slower rate during the slow phase, which can last several minutes, depending on the subject.

During high-intensity intermittent training, heart rate increases with load intensity, first linearly, then less markedly, reaching a kind of plateau. Relatively short pauses prevent the heart rate from dropping too low. (Hunziker R, 2005). Comparing HR for the same intensity during intermittent and continuous effort, HR reaches significantly higher peak values during intermittent effort (Gacon in Cometti G, 2002, Dellal A, 2008). The interest of HR is defined by its linear relationship with the evolution of VO_{2max} during a long effort (Nhaoua A, 2017). However, Dupont G and al, (1999) have shown that FCmax does not necessarily correspond to VO2max. The use and exploitation of HR during intermittent exercise must therefore be used with caution (Dellal A, 2008).

However, it should be remembered that intermittent training is now considered to be one of the most popular forms of training in team sports, particularly soccer (Dellal A, et al., 2010). Since analysis of the structure of intermittent sports activities has shown that they are characterized by frequent jumping, sprinting and changes of direction alternated with low-intensity walking or running (Haj Sassi R and al., 2009), high-intensity intermittent training, in its various forms, is today one of the most effective ways of improving cardiorespiratory and metabolic function and, in turn, the physical performance of athletes (Buchheit M and Laursen P.B, 2013). And in this respect, intermittent training has been the subject of much research in recent years.

The organization of intermittent work consists of programmed work phases at higher or lower target intensities, interspersed with periods of active or passive recovery (Assadi H, Cometti G. 2007; Dellal A and al., 2009). The individual programming of these sessions can simultaneously develop different physical qualities, depending on the choice of different characteristics of these intermittent exercises, such as the total duration of effort, the respective durations of effort and rest periods, or the intensity of the latter. The durations are directly linked to the intensity of the effort, but are also chosen with regard to the competitive activity (Buchheit M .2005 ; Ferre J, Leroux P. 2009).

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Short and long intervals are part of traditional high-intensity intermittent training (HIIT). Long intervals correspond to a long exercise duration (<8 minutes) with high intensity (90% - 100% VO_{2max}) and interspersed with periods of active (<60% VO_{2max}) or passive recovery lasting 1 to 3 minutes. For short intervals, the exercise duration is less than 60 seconds with high intensity (100% - 120% VO_{2max}) and interspersed with periods of active (<60% VO2max) or passive recovery lasting less than 1 minute (Buchheit.M and Laursen P.B, 2013a, 2013b).

Various studies have reported that HIIT is associated with the development of MAP (Assadi H and Cometti G, 2007) and the optimization of players' maximal oxygen uptake (VO_{2max}) (Dellal A and al., 2009), and that this training mode enables players to work longer than continuous exercise at the same intensity (Assadi H and Cometti G, 2007). However, given the short duration of intermittent exercise, intermittent training does not accumulate large quantities of lactate, and the lactate formed is metabolized during recovery (Dellal A, 2008).

The form of intermittent exercise represents the basis on which this study was founded: intermittent exercise can be performed either in line or with changes of direction. These changes can be half-turns, in which case they are defined as intermittent shuttle exercise, or lateral (Dellal A, 2008). In this case, according to analytical studies of the two activities (handball and soccer), the intermittent mode with change of direction suits them best, as long as the player during the match carries out courses at different intensities, with changes of direction (Ravier G and Bouzigon R, 2014; Dellal A and al., 2009).

The physiological responses of high-intensity in-line intermittent exercise have been the subject of several studies, and its impacts are well known, in contrast to shuttle intermittent, there are few studies that have highlighted it, and to our knowledge there has been no work that has addressed 10s-20s and 15s-30s intermittent.

In the present study, we compared the effects of intermittent 10s-20s effort at 100% and 110% of MAS in line and shuttle.

Dellal A, (2008, 2009) has already addressed in a comparative study, intermittent effort 10s-10s and 15s-15s in line and shuttle performed at 105%, 110% and 115% of MAS. The results showed significant differences between these two types of effort. Similarly, Buchheit M and al, (2010) argued in a comparative study between repeated line and shuttle sprint sequences, that 180° direction changes, may increase systemic metabolic load (i.e. cardiorespiratory and blood acidosis responses).

The aim of the present study is to explore the physiological adaptations to heart rate during intermittent 10s-20s and 15s-30s high-intensity exercise, and to shed light on the physiological impact of changes in direction during shuttle exercise, via the comparison of two types of protocol: one in line, and the other in shuttle with different intensities. Highlighting the physiological repercussions of changes in direction (deceleration and re-acceleration) during intermittent high-intensity shuttle effort is of great interest in quantifying intermittent training, given that quantifying training load is a recurring issue in team sports in order to improve athlete monitoring.

2. Method

2.1 Subject

Our experimental study was carried out on a sample of two groups of 10 healthy male subjects, both of whom were students at the Technical Sciences of Physical Activities and Sports, Mohamed Lamine Debaghine University, Sétif 2, The first group followed the first high-intensity intermittent exercise protocol (10s-20s), while the second group followed the second high-intensity intermittent exercise protocol (15s-30s).

Table N°1. The anthropometric, physical, and physiological characteristics of the group are as follows:

	Age	Weight	Height	MHR	RHR	HRR	[La]	MAS	LTim
Group 10s-20s Values S±D	22.5 ± 1.15	76.3 ± 4.6	178.7 ± 2	185.60 ± 7.41	56.6 ± 2.22	129 ± 8.95	1.87 ± 0. 2	97% ± 1.69	17,75 ± 0.54
Group 15s-30s Values S±D	22.3 ± 1.15	72.09 ± 6.13	179.4 ± 5	185.80 ± 6.32	55.8 ± 1.93	130 ± 7.46	1.92 ± 0.19	97.6 % ± 1.17	19.5 ± 0.97

2.2 Heart rate measurement

Heart rate was continuously recorded using a Polar Team2 Pro System heart rate monitor (fig.1). This is a device for determining instantaneous heart rate in team sports, thanks to flexible chest belts fitted with appropriate transmitters with electrodes for transmitting wireless signals corresponding to heartbeats, to a receiving station connected to a standard laptop computer with appropriate software for recording and analyzing heart rate in real time. Heart rate recordings were averaged every 5 seconds over all experimental sessions.

Variables measured:

*** Resting heart rate (RHR):** corresponds to the lowest heart rate recorded following a 15 min lying down session at 9:00 am.

*** Maximum heart rate (MHR):** corresponds to the highest rate recorded during a triangular exercise test (15-30 IFT test).

***Reserve heart rate (HRR):** corresponds to the maximum heart rate minus the resting heart rate: reserve heart rate = max heart rate - resting heart rate.

Figure N°1. Crdiofrequencemetre Polar Team[2]

2.3 Statistical analysis

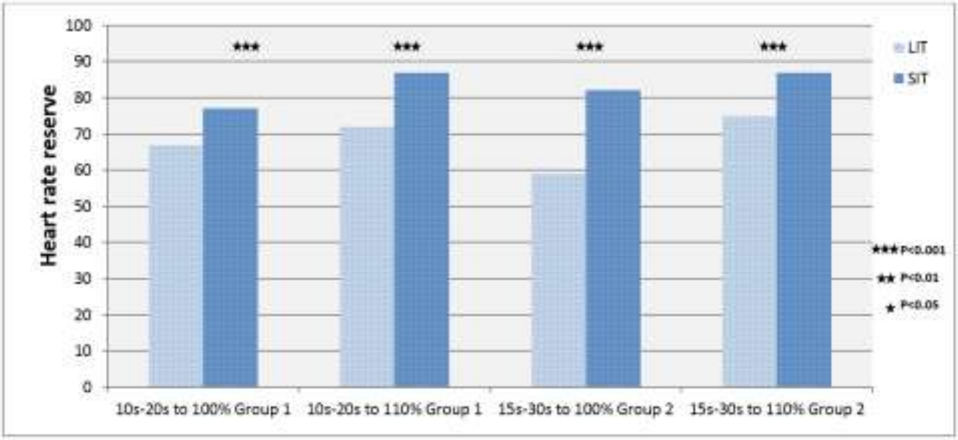
Data from the different sessions of the two experimental protocols were expressed as mean values ± SD. Statistical processing was carried out using SPSS for Windows (version 20; SPSS, Inc., Chicago, IL). Before comparing the results obtained in the different sessions of intermittent effort in line and in shuttle, we first opted for the statistical analysis of the normality of the distribution of variances according to the Kolmogorov-Smirnov test and the homogeneity of variances according to the Hartley test, the Student's t-test for paired series was used to perform the comparative analysis. When the conditions of normality and equality of variances of the distribution were not met, the Wilcoxon Signed Sum Rank test was used. The significance level retained for the comparative analysis as a whole is 5%, i.e. $p \leq 0.05$.

3.Results

3.1 Results for percentage of reserve heart rate (%HRR)

Statistical analysis (Fig.2) showed that there were significant differences ($p < 0.001$) between the different sessions of intermittent effort 10s-20s in line and in shuttle, performed at 100% and 110% of MAS by the first experimental group. Similarly, for the second experimental group who performed the sessions of intermittent effort 15s-30s, the results of statistical analysis also showed significant differences ($p < 0.001$).

Figure N°2. Comparison of the percentage of reserve heart rate (HRR) recorded during different online and shuttle intermittent exercise sessions.

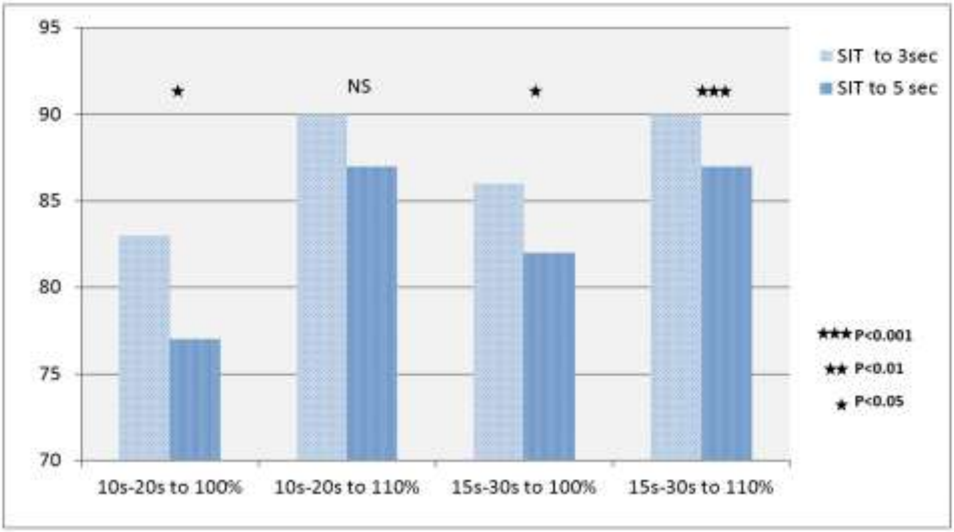


3.2 Results of the percentage of reserve heart rate (%HRR) during intermittent shuttle exercise with a variable number of changes of direction

The results of the statistical analysis (fig.3) show that the HRR recorded during the 100% intermittent shuttle exercise session with a change of direction every 3 sec, in the 10s-20s protocol, is significantly ($p < 0.05$) higher than that recorded during the shuttle intermittent effort session with a change of direction every 5 sec.

However, for the session performed at 110%, analysis of the results shows no significant difference. However, for the second 15s-30s protocol, analysis of the results showed significant differences ($p < 0.05$, $p < 0.001$ respectively) between the intermittent effort sessions with a change of direction every 3 sec, and 5 sec, performed at 100% and 110% of MAS.

Figure N°3. Comparison of the percentage of reserve heart rate (HRR) recorded during different online and shuttle intermittent effort sessions.



4. Discussion

The aim of the present study was to compare one of the physiological rewards, namely heart rate, of two forms of intermittent effort, line and shuttle at different intensities.

The results show significant differences ($p < 0.001$) in all 10s-20s and 15s-30s intermittent effort sessions performed at 100% and 110% of MAS, and it appears that cardiac demand is greater during 10s-20s and 15s-30s intermittent effort in shuttle mode, compared with intermittent effort in line mode (fig.2). These results contradict those of Dellal A, (2008, 2009) when comparing intermittent 10s-10s and 15s-15s in-line and shuttle effort performed at 105%, 110% and 115% of MAS, the author arguing that the short duration of the 10s-10s and 15s-15s protocol respectively (6min 50, 9min45) does not allow the body to adapt physiologically, and that Billat V.L and al., (1998) reported that the optimum time for the aerobic mechanism to be solicited is between 4 and 6 min. in this case, the results of this study are in line with those of Bisciotti and al, (2000), and Dellal A, (2008, 2009) in a comparison of two intermittent efforts 30s-30s in line and in shuttle. According to Dupont G, (2003) intermittent work is a mixed anaerobic and aerobic effort, with the contribution of aerobic metabolism increasing with repetition (Gaitanos G.C and al., 1993; Balsome P.D and al., 1994a, 1994b). However, intermittent exercise makes use of the stimulation of aerobic processes that occurs at the end of an effort that has caused an oxygen (O_2) debt in the athlete's body (Pradet M, 2002). Christensen E.H and al, (1960) reported that part of the energy required for muscle contraction comes from the reserves of this metabolism (O_2). These data support the findings of our study, i.e. that intermittent effort places significant demands on the cardiac system, and that changes in direction (deceleration, blocking, and acceleration) during intermittent shuttle effort increase aerobic energy requirements, which in turn stimulate the cardiac system.

In the present study, we tried to explore one of the physiological adaptations, i.e. heart rate, during a 10s-20s and 15s-30s intermittent effort at high intensity, and to shed light on the physiological impact of changes of direction during intermittent shuttle effort, by comparing two types of intermittent effort: an in-line protocol, and a shuttle protocol with a variable number of changes of direction, and different intensities. Highlighting the physiological repercussions of changes of direction, deceleration and re-acceleration during high-intensity intermittent shuttle effort is of great interest in quantifying intermittent training, bearing in mind that quantifying training load is a recurring issue in team sports in order to improve athlete monitoring.

Based on experimentation in the first part of our study, and statistical analysis of the results, it was found that intermittent shuttle training had a different impact on athlete performance than intermittent line training, and that blocking, acceleration and deceleration during the shuttle running protocol resulted in a significant increase in the average heart rate of the effort sequences,

Generally speaking, the difference in impact between intermittent effort in line and in shuttle is due, on the one hand, to the greater solicitation of the peripheral component by changes in direction, and on the other hand to the intermittent effort sessions in shuttle, despite the fact that the distances the subjects have to cover are mathematically calibrated with beeps, so that each subject runs at a speed equivalent to 100% and 110% of his MAS, we found that the subjects reached running speeds at the end of the acceleration phase that were higher (± 1. 5 km/h) than those calibrated in the effort session, taking into account the catching up accumulated at each deceleration and stoppage.

In the second part of our study, where we highlighted the physiological impact of the variability in the number of direction changes during intermittent shuttle effort, by comparing the heart rate response of two intermittent shuttle effort protocols 10s-20s and 15s-30s at 100% and 110% of MAS, with a variable number of direction changes, with one block every 3 sec in the first protocol and 5 sec in the second, the results (Fig.3) showed significant differences in all intermittent effort sessions with the exception of the 10s-20s session at 110%, it seems that 9 block differences between these two protocols had no significant effect unlike the other sessions where the difference in the number of blocks between the two protocols ≥ 18 blocks. Several authors have previously reported that the number of changes of direction during intermittent shuttle effort would instantaneously influence the energy cost of running and the athlete's performance, (Bisciotti N.G and al., 2000; Thompson D and al., 1999; Ahmaidi S and al., 1992).

5. Conclusion

Quantifying sports training loads is one of the most important challenges facing coaches and physical trainers, as the development of top-level sport today requires players to train at very high volumes and intensities throughout the sporting season, and that mismanagement in the distribution of these loads can be followed by the onset of chronic fatigue and injuries, so it's up to coaches and physical trainers to play their part by setting up an ideal load quantification model, enabling individual training management.

The results of our study revealed significant differences between physiological responses, namely heart rate during intermittent in-line and shuttle effort with the same intensity, and volume of work, and similarly with regard to the number of direction changes during intermittent shuttle effort, the latter influencing performance differently.

In this respect, for a rational and harmonious quantification of intermittent effort, the effect of deceleration, blocking and re-acceleration, and their number during shuttle effort, on the athlete's performance should be taken into consideration.

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