The purpose of this study was to evaluate the heart rate responses of the 2 Multiball Table Tennis interval training protocols during the competitive period on young Table Tennis players. Fourteen (n=14) players, aged 12±2yrs participated in this study. Participants were randomly divided into 2 training duration groups (15s vs. 30s) and were trained under the 2 interval protocols for 6 weeks (3 sessions. w⁻¹). Heart Rate (HR) data was electronically recorded by using the Polar Team System at the completion of each exercise at the 1st and 5th set in the 1st and 6th week. The Wilcoxon signed-rank test was applied in order to compare the repeated measurements, whereas Spearman’s rank correlation (ρ) analysis was employed to determine whether the testing parameters are significantly related. From the results it is shown that regarding to the HR both training protocols can simulate the match conditions. In both groups participants’ the footwork exercises with Forehand and Backhand strokes recorded the higher HR (190-210 b.min⁻¹). Additionally, significant HR differences were recorded in Group A (z=-2.023, p=0.043) in Footwork Forehand Backhand (FTFB). In conclusion, both Multiball protocols can generally simulate match conditions supporting the weekly training program of young Table Tennis players.

Key Words: Table tennis, Heart rate, Multiball, Training adaptations.
INTRODUCTION

The heart rate is expressed as the number of cardiac cycles per minute and is one of the most commonly used physiological indicators in sport and exercise sciences. From the late 19th century the counting of the heart rate is extendedly used in coaching for the evaluation of the athletes’ cardiorespiratory fitness. Specifically, in physical conditioning, the heart rate is an important component of the contemporary training which defines the intensity, the volume and the recovery periods of the exercise (25). The increased heart rate is the result of the activation of the sympathetic system while simultaneously the parasympathetic system is de-activated (12). The evaluation of the heart rate can be used in many ways and it can be directly applied by the trainer in everyday workout as a tool for the recording of the training progress (25, 13, 10).

Racket sports are characterized by repeated extremely short and short term maximal efforts with passive resting intervals, while the intensity of competitive playing performance could be very high depending on the level and the type of player (attacker-defender) as well as on the athlete’s gender and age (15, 21). During the racket sports matches the players’ heart rate approaches the age-related maximal, while the average values are often more than 75% of the maximal heart rate (18). For instance, in Tennis the heart rate can reach up to 87% of the maximal and it depends on the level, age and tactical requirements of the players (4, 23, 1). Similarly, in Badminton the heart rate can range from 80 to 95% of the maximal (11,20) something that also happens in Squash (24,8), while in Table Tennis the heart rate reaches the 90.3% of the players’ maximal heart rate (26).

Table Tennis is considered an aerobic activity with occasional anaerobic involvement (19). The nature of Table Tennis makes the planning of the training process complicated because of the required physiological demands. From the coaching perspective two types of training methods are used: the continuous and the interval. The continuous method is the most common one, while the interval training with the use of the Multiball has been recently presented as a method for the enhancement of the playing performance in Table Tennis. The advantage of the Multiball method is that it simulates the match conditions while, at the same time it develops the players’ strokes accuracy, aiming on the high intensity and quality training (12).

According to our knowledge, there is not any available study in the bibliography which has assessed the effect of the Multiball training as a tool for tracking the young players’ performance progress during a training program. Therefore, the aim of the present study was to evaluate the effects of the two interval protocols with the use of the Multiball training on young Table Tennis players’ heart rate during the competitive period.
METHODS

Subjects

Fourteen (n=14) players, nine (n=9) boys and five (n=5) girls were recruited for the study. Their mean age and specialization in Table Tennis was 12±2yrs and 3±1yrs respectively. The selection of this study’s participants was based on the criteria: i) to compete in the National Youth Table Tennis Tournament, ii) to have active Ranking List points, iii) the frequency of training (5 sessions’ per-week), iv) the training experience (greater than 3yrs) and v) do not were under drug treatment. The participants anthropometric characteristics of stature (152 ± 0.50cm) and body mass (46.6 ± 3.9kg) were firstly recorded. Body mass was measured at the nearest 100g on a calibrated floor scale (Seca 770). The subject was standing in the center with relaxed arms, without shoes and wearing only light sportswear. Stature was measured with a stadiometer (Seca 240) at the nearest 0.1cm in bare feet with the head in Frankfort horizontal plane. The maximal heart rate (HRmax) of the players was estimated by using running bouts of a modified Bruce protocol in a motorized treadmill (2). Parents were informed about the study and were asked to complete a written informed consent prior to their children’s participation. The study was performed according to the rules of the Ethics Committee of the Democritus University of Thrace.

Procedures

The anthropometrical measurements applied to this study participants two days before the start of the training intervention. After the baseline assessment completion the participants were divided in two equal capacity groups according to the results of Table Tennis Specific Battery Test [7]. The Multiball interval training protocols which applied in the current study differed only in the duration of exercise (A:15s & B:30s), while the balls launch rate was 80balls. min⁻¹. The research lasts 6 weeks with 3 training sessions per week with the players do not have any additional training session or match during that period. Aside from time and launch rate each Multiball protocol followed by the same training procedures:

- Warm Up 10±5min (5min jogging & low intensity general exercises)
- Cool Down 5min of stretching
- Walking between sets

The mixed time (exercise/rest) of the training protocols was 12:45s for the Group A and 19:30s for the Group B. Both groups players’ had to play a forehand counter drive (FHCD), a backhand counter drive (BHCD) and a footwork exercise
with forehand and backhand counterdrives (FTFB) or marking in diagonal axis continually (MX). According to the testing protocol the balls were served by an experienced instructor in the forehand and backhand side of the players. The accuracy and the effectiveness of the studied players technique recorded electronically, (Figure 1,2,3). Both groups had to perform 5 sets of each exercise with 1:1 resting intervals. After the completion of each set a 3min recovery period applied. Launch rate of 80balls min⁻¹ was selected in order to meet the match rallies (9). Such high rates are also used in different measurement protocols (3) because they constitute a quick but representative rate according to the profile of the sport. (22)

![Graphical representation of the technical set-up of forehand counterdrive (FHCD), backhand counterdrive (BHCD) and the players’ footwork in forehand and backhand counterdrives (FTFB).](image)

The training heart rate data was recorded at the completion of each exercise at the 1st set and finishing the 5th set of third exercise using the Polar Team System (Polar Electro Oy, Kempele, Finland). The heart rate data of the players’ was analyzed by the use of the Polar Precision Performance 3.0 Software. 2 digital HD cameras (Sony HDR-GW55) were used to record exercises and to analyze the players’ performance afterwards. The participants’ heart rate was measured pre and post the training period of 6 weeks. The training procedures and measurements were performed in the same sports hall while the Table Tennis tables were Stag and the balls were Butterfly 40mm.

**Statistical Analysis**

The data normality was checked by using the Kolmogorov-Smirnov analysis. In addition, the scatterplots were used in order to determine whether a linear model
is reasonable for the variables of players’ performance in relations to the interval training protocols. Descriptive statistics with exploration and cross-tabulation were firstly generated for the continuous variables of heart rate (min-max) of both groups in every exercise. Wilcoxon signed-rank test was utilized in order to compare the repeated measurements, whereas Spearman’s rank correlation (ρ) analysis was employed to determine the testing variables that are significantly related. All data analysis was performed by means of the IBM-SPSS statistical software 19.0 for Windows (SPSS, Inc., Chicago, IL). The statistical significance was set at p<0.05

RESULTS

Heart rate values ranged from 111 to 210 b.min⁻¹ for the participants of the Group A (15s) as well as from 110 to 192 b.min⁻¹ for the players of Group B (30s). The greatest heart rate values were recorded in FTFB exercises for both groups in 5th set which was close to maximum heart rate of the studied players with the heart values in FH and BH exercises to range between 186 and 126 b.min⁻¹. The descriptive statistics of the recorded heart rate values of players’ of Group A and B are demonstrated in figures 4 and 5.

Figure 4. The Group A players’ mean resting and exercise heart rate.
Figure 5. The Group B players’ mean resting and exercise heart rate.

Abbreviation:  
FHCD: Forehand Counterdrive,  
BHCD: Backhand Counterdrive,  
FTFB: Footwork Forehand Backhand

The mean values for each testing parameter were compared in the 1st and 5th week by the Wilcoxon signed rank test. Differences in the mean values were found significant for FTFB parameter in Group A. ($z=-2.023$, $p=0.043$) while no significant difference was observed in Group B, (Table 1).

Table 1. The Wilcoxon signed-rank test critical values of the players.

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th></th>
<th>Group B</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FHCD61-</td>
<td>FHCD65-</td>
<td>BHCD61-</td>
<td>BHCD65-</td>
<td>FTFB61-</td>
</tr>
<tr>
<td></td>
<td>FHCD11</td>
<td>FHCD15</td>
<td>BHCD11</td>
<td>BHCD15</td>
<td>FTFB11</td>
</tr>
<tr>
<td>FHCD61-</td>
<td>.854*</td>
<td>.080</td>
<td>.715</td>
<td>.068</td>
<td>.043</td>
</tr>
</tbody>
</table>

* $p<0.001$, $\neq p<0.05$
A series of Spearman rank-order correlations were conducted in order to determine if there were any relationships between heart rate values and testing variables. A two-tailed test of significance indicated that there was a significant positive relationship in Group A. between the FHCD11 and FTFB11 ($\rho = .95, p< .001$) and FTFB15 ($\rho = .92, p< .001$), in FHCD15 and FHCD65 ($\rho = .97, p< .001$), in BHCD15 and FTFB11 ($\rho = .86, p< .001$) and FHCD65 ($\rho = .97, p< .001$), in FTB15 and BHCD61 and BHCD65 which had perfectly positive correlation ($\rho = .100, p< .001$). There was also considerable positive relationship in FHCD65 and FTB61 and FTB65 ($\rho = .97, p< .001$). In Group B, there is a strong negative relationship in FHCD61 and FHCD11, BHCD11, BHCD15, FTB11, FTB15 ($\rho = -.100, p< .001$). Positive correlations were noted in FHCD11 and BHCD11 ($\rho = .94, n= 6, p< .001$) and BHCD15 ($\rho = .92, p< .001$). FHCD15 and BHCD61/FTB65 had perfectly positive correlation ($\rho = .100, p< .001$). BHCD11 had significant positive correlation with BHCD15 ($\rho = .98, p< .001$). The table 4 illustrates the Spearman correlations between each testing protocol parameters. A significant correlation was recorded in Group A.

**Table 2. Linearity evaluation (Spearman’s $\rho$ correlation coefficients) of the players’ performances in relation to the testing parameters.**

<table>
<thead>
<tr>
<th>Testing Parameters</th>
<th>$\rho$</th>
<th>$p$ values</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group A</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHCD11-FTFB11</td>
<td>.95</td>
<td>.001</td>
<td>sig.</td>
</tr>
<tr>
<td>FHCD11-FTFB15</td>
<td>.92</td>
<td>.001</td>
<td>sig.</td>
</tr>
<tr>
<td>FHCD15- FHCD65</td>
<td>.97</td>
<td>.001</td>
<td>sig.</td>
</tr>
<tr>
<td>BHCD15-FTFB11</td>
<td>.86</td>
<td>.001</td>
<td>sig.</td>
</tr>
<tr>
<td>BHCD15-FHCD65</td>
<td>.97</td>
<td>.001</td>
<td>sig.</td>
</tr>
<tr>
<td>FHCD65-FTFB61</td>
<td>.97</td>
<td>.001</td>
<td>sig.</td>
</tr>
<tr>
<td><strong>Group B</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHCD11-BHCD11</td>
<td>.94</td>
<td>.001</td>
<td>sig.</td>
</tr>
<tr>
<td>FHCD11-BHCD15</td>
<td>.92</td>
<td>.001</td>
<td>sig.</td>
</tr>
<tr>
<td>BHCD11-BHCD15</td>
<td>.98</td>
<td>.001</td>
<td>sig.</td>
</tr>
</tbody>
</table>
DISCUSSION

The main finding of this study was that the two training Multiball protocols differentiate the training responses of the young table tennis players. In the amount of studied players the HR were increased during both Multiball interval training protocols. At the beginning of the study the players' HR was 111-119 b.min\(^{-1}\) for Group A (15s) and 110-119 b.min\(^{-1}\) for Group B (30s), whereas at the 6\(^{th}\) week it reached 190-210 and 192 b.min\(^{-1}\) respectively. These findings may indicate that both training protocols can simulate match conditions and are in conjunction with other similar studies in which the players' HR rank from 110-170 to 191-199 b.min\(^{-1}\) (16,5). Moreover, similar with another racket sports study, the above results show that the players' heart rate during the Multiball training corresponds to the heart rates in match conditions (11).

Concerning the heart rate during specific exercises our results demonstrate that values of the players' exceed 180 b.min\(^{-1}\) in footwork exercises (FTFB15 and FTFB65) in both Groups, while in simple Forehand and Backhand Counterdrive remain under 180 b.min\(^{-1}\). In particular, at the beginning of the first week of the Multiball training, the players’ HR\(_{\text{Mean}}\) (FHCD15) was 169.2 b.min\(^{-1}\) in the Forehand Counterdrive in Group A, whereas at the completion of the sixth week the HR\(_{\text{Mean}}\) (FHCD65) was 180.6 b.min\(^{-1}\). Additionally, concerning the Backhand Counterdrive the HR\(_{\text{Mean}}\) (BHCD15) was 150 b.min\(^{-1}\) and 166.2 b.min\(^{-1}\) at the first and sixth week respectively. Launch rate of 80 balls.min\(^{-1}\) was the same in every exercise in both groups. The higher heart rate values can be explained by the complexity of exercises. When the exercise demands footwork and different use of strokes (Forehand/ Backhand) heart rate values are increasing. Similar results were drawn in other studies concerning Heart Rate and type of stroke, footwork and level of players (6,14,27).

Although, the results confirmed significant difference only between the Footwork Forehand/Backhand Counterdrive (FTFB) in Group A, the HR values in the majority of the tests were lower in the beginning of exercises comparing first and last week in both groups. Therefore, specific adaptations occurring in HR during Multiball training can be verified by multiple significant correlations between variables in both groups. Currently, the present study is the first study which compares different protocols and Multiball training. Although effect of Multiball training on table tennis performance was not investigated, it was noticed that heart rate values were influenced by complexity of exercises and special adaptations.
CONCLUSION

Conclusively, the current study is the first which scientifically evaluates the Heart Rate responses of Table Tennis players under two different Multiball training protocols. The major finding of this study was that both training protocols which were applied with the current study open the “window of cardiorespiratory adaptations” in young Table Tennis players. If main efforts are to simulate match conditions both testing protocols can support training program and can be important for the coaches. Further research for a longer time and in a variety of muscle endurance protocols of the Multiball method possibly could be the “key” point for the playing performance enhancement and perceived exertion in Table Tennis players.

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