Effects of Pre-Exercise Activities on Progressive Cycling Test Performance and Autonomic Response

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ABSTRACT

Dos-Santos RC, Costa CRM, Di Masi F, Silveira ALB. Effects of Pre-Exercise Activities on Progressive Cycling Test Performance and Autonomic Responses. JEPonline 2014;17(5):84-94. Recent reviews have shown detrimental effects of muscle stretching before sports activity. In addition, controversial results have been presented on the benefits of warming up. This purpose of this study was to evaluate the influence of a pre-exercise warm-up and ballistic stretching on performance and heart rate variability during an incremental cycle ergometer test. The subjects were untrained physically active men who were familiarized with the cycle test on day 1, which was followed by three protocols (Control, Warm-Up, and Ballistic Stretching) separated by at least 48 hrs. After each protocol, the subjects performed a maximal incremental cycle ergometer test. The warm-up did not have any influence on the test performance compared to the control (P>0.05). Both the total test time and maximal sustained load decreased after the ballistic stretch protocol (P<0.05). The cardiovascular and autonomic variables did not show any statistical difference between protocols. Thus, the results indicate that ballistic stretch impaired performance and warm-up did not show any beneficial effect. Both pre-exercise activities should be used carefully just prior to an athletic performance.

Key Words: Heart Rate Variability, Ballistic Stretch, Warm-Up
INTRODUCTION

Since a difference of just a few seconds in a sports competition may mean the loss of a gold medal, it is important to understand the influence of pre-exercise activities such as a warm-up. While it is believed that a warm-up is necessary to improve performance, the effects of a warm-up on the physiology of exercise are still unclear (7,17,18). In fact, despite being part of the recommended guidelines for a safe exercise prescription (19) the beneficial effects of this activity are regularly based on the coach’s personal experience rather than scientific studies (18).

In general, a warm-up consists of low-intensity aerobic exercise, a stretching session, and sports-specific movements (18). Although there is little evidence to indicate that a warm-up is harmful, there are reports (6,7,52) of particularly long and intense warm-ups causing fatigue and impaired performance (46). In order to understand the effects of a warm-up on sports performance, each component should be studied separately (18).

Muscle stretching can impair performance in power or strength-dependent activities when used prior to exercise (33,39,43,44). However, ballistic stretching routines are becoming more common prior to exercise due to a reduced impairment of performance in various activities (5,40). Additionally, Bacurau et al. (3) stated that ballistic stretching could be more appropriate because a decrease in muscle strength seems less probable. Nonetheless, there are discrepancies whether ballistic stretching improves, impairs or has no effect on performance (37,42). There are no studies, to our knowledge, that report ballistic stretch-induced impairments to subsequent performance on endurance-dominant activities.

Optimal endurance exercise performance correlates with autonomic activity through a higher parasympathetic activity at rest (8,9). Efferent autonomic activity may be measured by the indirect method of heart rate variability (HRV), which assesses autonomic control over the heart (14). Also, HRV has been shown to be effective in both physiological and pathological conditions (48). Previous work from our laboratory has shown that when ballistic stretching was used as prior sprint running, the vagal modulation was higher than warm-up during a high intensity running exercise (13). Yet, there is a gap of knowledge regarding the effects of ballistic stretching on autonomic modulation during an incremental cycling exercise.

The purpose of the present study was to evaluate for the first time the effectiveness of different components of a warm-up session as low intensity aerobic exercise and ballistic muscle stretching on autonomic activity and performance in an incremental maximal cycling test. The experimental protocol was designed to evaluate each warm-up component separately, to avoid any interference on results between them. The primary hypothesis was that the inclusion of a low-intensity aerobic exercise component to the warm-up would impair performance and reduce parasympathetic modulation. The secondary hypothesis was that the dynamic stretching component would improve subsequent performance and parasympathetic modulation compared to the low-intensity aerobic exercise.

METHODS

Subjects
The sample size was established in accordance with studies with similar methods that produced clear results (26). Nine untrained males (age = 22 ± 1 yrs; height = 174 ± 2.6 cm; weight = 74.2 ± 2.6 kg; body fat = 8.6 ± 2.8%) were selected to participate in this study.
Each subject read, filled out, and signed a consent form, which was approved by the Institutional Ethics Committee under protocol 23083.010576/2011-79 in accordance with Resolution 196/96 from National Health Council. In the consent form, a complete explanation of all experimental steps was presented. The subjects were instructed to avoid: (a) strenuous exercise for 24 hrs prior to the cycling test; (b) alcohol and caffeine consumption; and (c) taking drugs with autonomic effects.

**Test Validity**
We used a maximal incremental cycle ergometer test similar to the test proposed by Özcelik and Kelestimur (36). The test consisted of a cycle ergometer challenge (ERGO-FIT® – Ergo 167 Cycle, Pirmasens, Germany) of which the load was started at 100 watts (W) that was then increased progressively by 5 W/20 sec. In accordance to Grazzi et al (23), when hyperventilation was evident the load increment shifted to 10 W/20 sec until exertion. In order to assess the measurement stability of the test, each subject performed the maximal incremental cycle test for three consecutive days without any pre-exercise activity. The measure was stable with a coefficient of variation equal to 3.82%.

**Experimental Protocols**
The experimental protocols had a randomized crossover design that consisted of three procedures separated by at least 48 hrs. One week before the exercise tests, the subjects underwent anthropometric measurements and a familiarization session for each procedure used in this study. During the control protocol (CTRL), the subjects rested for 3 min. During the warm-up protocol (WU), the subjects cycled at a 70 W load while maintaining 60 rev·min⁻¹ for 3 min, as described by Bishop (7). During the ballistic stretch protocol (BS), the subjects performed 6 sets of 30 sec of ballistic stretching related to cycling movements. The muscles that were stretched throughout the 3 min of ballistic stretching included the abdominal region, lower back, hamstrings, gluteals, hip adductors, quadriceps femoris, gastrocnemius, and soleus muscles.

In order to discriminate the effects of aerobic warm-up or stretching on performance, the subjects in the control protocol performed a maximal test without any pre-exercise activity despite the recommendations of current guidelines (1,24,27,32). To maintain the same rhythm between the ballistic stretch and the warm-up protocols, a metronome was used at 60 beats·min⁻¹ in accordance with previous work (13,53). After each experimental protocol, the subjects performed the maximal incremental cycling test in a controlled environment (temperature ~23°C, humidity ~50%). Total time was determined using a Timex Marathon Stopwatch - t5g811 (Connecticut, EUA).

**Heart Rate Analysis**
The subjects’ HR was recorded during the entire experiment by a Polar RS800CX (Polar Electro OY, Kempele, Finland), which was validated in previous studies (28,35,38). After R wave peak detection, tachograms were generated during each protocol and exercise tests, containing all heart period fluctuations within this time segment. In the time-domain, the following indexes were obtained: (a) mean interval between R wave peaks (RR); and (b) square root of the mean squared differences of successive RR intervals (RMSSD). For spectral analysis (frequency-domain) of HRV, tachograms were resampled to equal intervals at 4 Hz and the linear trend was removed. The power spectrum was obtained with a fast Fourier transform based method (Welch’s periodogram: 256 points, 50% overlap, and Hanning window). Three frequency bands were determined: (a) very low frequency (VLF: 0.0 – 0.04 Hz); (b) low frequency (LF: 0.04 – 0.15 Hz); and (c) high frequency (HF: 0.15 – 0.4 Hz). Low frequency and HF were normalized by the equations LF(n.u.) = LF ÷ (LF + HF) or HF(n.u.) = HF ÷ (LF + HF) (10). All HRV analyses were performed by Kubios HRV software (version 2.1; Biomedical Signaling and Medical Imaging Group, Kuopio, Finland).
Statistical Analysis
The Shapiro-Wilk test was used to determine the normality of the variables. All normal variables were compared using one-way ANOVA with repeated measures and Tukey’s post-hoc test. For variables with non-Gaussian distributions, the Friedman test and Dunn’s post-hoc test were used. All statistical procedures were performed using Graphpad Prism (Version 6.0; Graphpad Software Inc., California, USA).

RESULTS
All data is described as mean ± standard deviation. In order to reduce the high data variation found on total time and maximal load, both variables were normalized. The results demonstrated that total time on incremental cycling exercise was significantly impaired after ballistic stretching when compared to the control and warm-up protocols, with no differences between control and warm-up (CTRL = 1 ± 0; WU = 1 ± 0.12; BS 0.9 ± 0.07, p < 0.05) (Figure 1A). Similarly, the maximum load decreased after ballistic stretching when compared to the control and warm-up protocols, but also with no significant change between the control and warm-up (CTRL = 1 ± 0 W; WU = 1.048 ± 0.038 W; BS = 0.91 ± 0.068, P≤0.05) (Figure 1B). Ballistic stretching impaired performance by decreasing total time and maximal cycle load while the warm-up did not influence total time and maximal workload.

Figure 1. Performance on Maximal Cycling Test after Different Pre-Exercise Protocols. Total time (A) and maximal load (B) sustained to exhaustion in cycling incremental exercise expressed in normalized units (n.u.). CTRL (control), WU (warm-up), BS (ballistic stretching). *Represents a significant difference compared with controls (*P≤0.05; **P<0.001); #Represents a significant difference compared with WU (#P≤0.05). Values expressed as mean ± standard deviation.

Addressing HRV during each pre-exercise protocol, all variables in time (HR, RR, and RMSSD) and frequency domain (LF, HF, and LF/HF) were different from the control protocol (P≤0.05) with no difference between them (Table 1). However, no statistical differences were observed in both time and frequency domain (P>0.05) during the maximal incremental exercise test (Table 2). Therefore, the differences found in total time and maximal workload seem to be independent of autonomic modulation.
Table 1. Heart Rate Variability Responses in Time and Frequency Domain during the Pre-Test Protocols.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Warm-Up</th>
<th>Ballistic Stretching</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heart Rate</strong> (beats·min⁻¹)</td>
<td>73.6 ± 7.7</td>
<td>121.4 ± 20.9*</td>
<td>127.2 ± 12.4*</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>R-R interval (ms)</td>
<td>829.7 ± 96.5</td>
<td>507.6 ± 85.3*</td>
<td>483 ± 48.1*</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>RMSSD (ms)</td>
<td>53.7 ± 18.9</td>
<td>7.1 ± 5.6*</td>
<td>9.7 ± 4.5*</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LF (n.u.)</td>
<td>0.66 ± 0.12</td>
<td>0.84 ± 0.06*</td>
<td>0.84 ± 0.10*</td>
<td>0.03</td>
</tr>
<tr>
<td>HF (n.u.)</td>
<td>0.33 ± 0.11</td>
<td>0.16 ± 0.06*</td>
<td>0.15 ± 0.11*</td>
<td>0.03</td>
</tr>
<tr>
<td>LF/HF</td>
<td>2.5 ± 1.3</td>
<td>5 ± 1.5*</td>
<td>6.5 ± 3.7*</td>
<td>0.02</td>
</tr>
</tbody>
</table>

RMSSD (Root Mean Square of the Successive Differences); LF (Low-Frequency); HF (High-Frequency); n.u. (normalized units); *Statistically significant difference vs. the control group (P<0.05). Values expressed as mean ± standard deviation.

Table 2. Heart Rate Variability Responses in Time and Frequency Domain during the Maximal Cycle Ergometer Test.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Warm-Up</th>
<th>Ballistic Stretching</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heart Rate</strong> (beats·min⁻¹)</td>
<td>153.9 ± 11.6</td>
<td>158.7 ± 15.5</td>
<td>157.8 ± 16.1</td>
<td>0.4657</td>
</tr>
<tr>
<td>R-R interval (ms)</td>
<td>399.2 ± 32.2</td>
<td>388.2 ± 40.1</td>
<td>389.3 ± 42.2</td>
<td>0.5395</td>
</tr>
<tr>
<td>RMSSD (ms)</td>
<td>4.2 ± 1.4</td>
<td>4.6 ± 2.2</td>
<td>4.2 ± 1.4</td>
<td>0.5469</td>
</tr>
<tr>
<td>LF (n.u.)</td>
<td>0.9 ± 0.04</td>
<td>0.8 ± 0.15</td>
<td>0.9 ± 0.14</td>
<td>0.5690</td>
</tr>
<tr>
<td>HF (n.u.)</td>
<td>0.2 ± 0.12</td>
<td>0.2 ± 0.15</td>
<td>0.2 ± 0.14</td>
<td>0.5690</td>
</tr>
<tr>
<td>LF/HF</td>
<td>7.7 ± 4.4</td>
<td>6.7 ± 2.9</td>
<td>9.0 ± 5.1</td>
<td>0.2872</td>
</tr>
</tbody>
</table>

RMSSD (Root Mean Square of the Successive Differences); LF (Low-Frequency); HF (High-Frequency); n.u. (normalized units); Values expressed as mean ± standard deviation.

DISCUSSION

Following the recommendations of Fradkin et al. (18), the purpose of this study was to evaluate the effects of two different pre-exercise activities (i.e., the warm-up and the ballistic stretch exercise) on an incremental cycle ergometer test. The findings indicate that the warm-up did not have an influence on the subjects' total time or maximal workload. These results are in accordance with previous studies (1,13,18,33,39,41,43,44,50) that found no alterations in performance due to the low intensity short protocol as a pre-exercise activity. Hence, the activity itself was designed to avoid fatigue, bearing in mind the intrinsic relationship of fatigue and the decrements caused by a warm-up (15,46). Ballistic stretching was addressed in this work because it was considered less likely to decrease performance in comparison with other stretching protocols (5,40).
Possibly, the low intensity short protocol failed to induce changes in physiological factors that are generally thought to influence the warm-up effects (e.g., muscle temperature, nerve conduction velocity, and muscle enzymatic cycling along with a decrease in muscle viscosity) (7). Moreover, Wittekind and colleagues (51) demonstrated that different intensities of a warm-up alter some metabolic variables and yet, the effects often disappear during maximal exercise. Gray and Nimmo (22) found similar results when comparing active, passive, and no warm-up protocols. The changes induced by the experimental protocol also disappeared during maximal exercise. Thus, in the present study the responses achieved by warm-up were rapidly counterbalanced during maximal exercise, which explains the absence of alterations on performance.

Several studies (2,3,16,29) have demonstrated that the ballistic stretch protocol results in a better performance compared to the static stretch protocol. However, fewer studies have compared the ballistic stretch protocol to a no-stretch protocol. This is an important point, as indicated by Behm and Chaouachi (5) and Turki et al. (47), especially since the dynamic stretches may induce post-activation potentiation (PAP) and may increase cross bridge cycling via an increase in myosin phosphorylation of the regulatory light chains (45). There may also be neural potentiation that results in a decrease of fast twitch motor unit thresholds, which is related to an increase in motor unit recruitment and firing frequency (30). The increase in firing frequency may relate to an increase rate of force development (34).

Interestingly, the present study found that the ballistic stretch protocol resulted in a decrease in total time and maximal workload in the progressive cycling test. This resulted in impaired performance compared to the warm-up and the control protocols. This finding is in agreement with the findings of two studies (4,31). It is possible that the ballistic stretch protocol reduced high-energy phosphates (7,40), which has a minimal influence on sprint exercises (21,40). But, it is reasonable to think the reduction in high-energy phosphates has a greater effect on activities that involve repetitive high-intensity contractions to failure (25), as in the exercise used in the present study. Also, the ballistic stretch may have decreased muscle blood flow and increased metabolite accumulation in the exercised muscles (4).

Perhaps, as a result of the negative physiological responses related to ballistic stretch, the protocol culminated with a PAP impairment that promoted a premature fatigue. The end result translated in a reduced total time and a decrease in muscle strength as indicated in the reduced maximal workload during the test. It should be highlighted that other studies (11,49) have also used ballistic stretching as a pre-exercise activity and found conflicting results compared to this study. But, none of the earlier studies used an incremental graded cycle exercise test.

It could be argued that a slight significant impairment in total time and workload is not clinically meaningful and, therefore, is inconsequential for a recreational athlete. Yet, on the other hand, the slight impairment might prove to be very substantial to an elite athlete.

While HR was significantly higher in both the warm-up and ballistic stretch pre-exercise protocols versus the control condition, HR was not statistically different between the two. This change was accompanied by HRV variables in time domain, in which all variables related to R-R interval decreased during both protocols. This change was expected since the subjects remained at rest during the control condition, but did in fact engage in some activity during both the warm-up and the ballistic stretch conditions. Nonetheless, no changes were found during the incremental graded cycle test. Thus, none of the protocols modified the dynamics of the cardiovascular response to strenuous exercise.
Gladwell and colleagues (20) reported that a lower high-frequency (HF) response during exercise is associated with a higher risk of cardiac arrhythmias. Hence, neither the warm-up HF response nor the ballistic stretch HF response in the present study would suggest a greater cardiovascular protection since there was a significant decrease in HF after both pre-exercise protocols during incremental exercise test. These results are contrary to those of our previous study that showed a higher HF after a ballistic stretch protocol during a high intensity short duration running test (13). The likely explanation is that the exercise applied in this study was a cycle test, which lasted longer and allowed the subjects to reach steady state that influenced the autonomic responses during the exercise.

CONCLUSIONS

The ballistic stretch protocol prior to sports activities should be carefully analyzed, especially since it may impair performance during a graded cycle exercise. While the changes found in this study may seem small, they are very important in the context of competitive sports. Meanwhile, the warm-up did not change any of the variables that were analyzed and seems to be unnecessary as a pre-exercise practice to improve performance. Also, the pre-exercise activities did not influence autonomic modulation. More research is necessary to shed additional light on the physiological responses with and without the traditionally accepted pre-exercise activities and the role each may play in general sports practice.

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