Effect of Ischemic Preconditioning on Land-Based Sprinting in Team-Sport Athletes

Neil Gibson, James White, Mhari Neish, and Andrew Murray

Purpose: The study aimed to assess whether exposure to ischemic preconditioning (IPC) in a trained population would affect land-based maximal sprinting performance over 30 m. Methods: Twenty-five well-trained participants regularly involved in invasion-type team-sport events were recruited to take part in a randomized crossover study design. Participants underwent both an IPC and a placebo treatment involving 3 periods of 5-min occlusion applied unilaterally (3 × 5-min occlusion to each leg) at either 220 mmHg or 50 mmHg, respectively. Each period of occlusion was followed by 5 min of reperfusion. After treatment, 3 maximal sprints over a distance of 30 m were undertaken from a standing start interspersed with 1-min recovery. Split times were recorded at 10, 20, and 30 m. Results: No significant effects of the IPC treatment were observed on sprint speed (P < .05) at any of the split timings; however, a small and negative effect was observed in female participants. Calculated effect sizes of the treatment were found to be trivial (<0.2). Conclusions: Results from the current study suggest there to be no benefit to team-sport players in using IPC as a means of enhancing sprint performance over a distance of 30 m. While IPC has been shown to be beneficial to sprint activities in other sports such as swimming, further research is required to elucidate whether this is the case over distances associated with land-based events in track and field or in events reliant on repeated-sprint ability.

Keywords: priming agent, sport, performance, warm-up

Myocardial infarction is recognized as a major cause of death throughout the world in both men and women. Research has shown, however, that it is possible to render the myocardium less susceptible to damage caused by ischemic episodes. The methodology by which this was achieved is known as ischemic preconditioning (IPC) and involves subjecting the heart to short-term ischemia followed by periods of reperfusion. Since the early research, the benefits of IPC on this myocardium have been well documented, along with beneficial effects on other tissues in the body.

The positive effects of IPC appear to depend on specific metabolites’ reaching a critical level. Along with bradykinin and opioids, adenosine has been identified as exerting an important role in the protective mechanism offered by IPC. It is suggested that adenosine released during occlusion stimulates A1 receptors, which have a protective effect even after the adenosine has been removed. Indeed, an intracoronary infusion of adenosine was found to exert the same protective effect as a 5-minute bout of occlusion. Research has demonstrated that inhibition of one of these metabolites (adenosine, bradykinin, or opioids) removed the protective effect of a single bout of IPC, leading to the assertion that a threshold existed below which occlusion would provide no observable benefit. Using multiple episodes of IPC, however, may facilitate reaching such a threshold. Indeed, it is not only the action of ischemia that has a beneficial effect but also that of reperfusion, especially in the early stages after ischemia.

There is mounting evidence that IPC may exert a positive effect on skeletal-muscle function, resulting in an increase in exercise capacity. In a group of well-trained cyclists there were improvements in total work, total exercise time, and power output after IPC treatment both before and after exercise when compared with a control group (no IPC). In that study there was a significant increase in power output of 4%. It should be noted that these performance changes were not paralleled by changes in measures of VO2max or VO2peak. It was proposed that the improved performance may have been a result of greater force generation through augmented neural drive and/or a reduced perception of fatigue. The authors of the aforementioned study conducted further trials using IPC on anaerobic capacity, finding no significant effect of the treatment on supramaximal efforts. Similar findings were observed in a group of well-trained participants for peak power output in a cycling task, accompanied by a significant and parallel increase in VO2max. Data presented for national-level swimmers showed IPC to improve 100-m performance on their preferred stroke by 0.7 second. This would appear to have practical significance, given...
and Resting Blood Pressure, Mean ± SD

Table 1 Participants’ Physical Characteristics and Resting Blood Pressure, Mean ± SD

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>22.9 ± 3.2</td>
</tr>
<tr>
<td>Stature (cm)</td>
<td>175.5 ± 9.0</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>75.5 ± 13.3</td>
</tr>
<tr>
<td>Resting systolic blood pressure (mmHg)</td>
<td>131.2 ± 15.2</td>
</tr>
<tr>
<td>Resting diastolic blood pressure (mmHg)</td>
<td>78.0 ± 11.1</td>
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</tbody>
</table>

a difference of 0.11 second separating gold- and silver-medal positions in the men’s 100-m freestyle final in the Beijing Olympics. It is interesting that no significant effect was observed on submaximal performance.

From the cited research it has been suggested that IPC may have a function in elite sport as a form of “natural doping,” offering the potential for enhanced performance. Not all sports, however, require periods of intense effort similar to those used in cited methodologies. For team-sport athletes there is the requirement for short accelerative actions rather than periods of sustained effort at maximal or near-maximal levels. Research using sprint- and power-based protocols has suggested IPC to exert a beneficial effect on sprint speed and countermovement-jump velocity when used as a recovery modality after fatiguing exercise of a similar nature. The current investigation was designed to assess whether IPC has an effect on maximal land-based sprinting over distances associated with competitive match play in a number of invasion sports. We hypothesized that due to the relatively short sprint duration, the beneficial effects of IPC would not be realized through an improvement in sprint times.

Methods

Participants

Twenty-five participants (16 men and 9 women) volunteered to take part in the study, all with a recognized competition history in the invasion sports of soccer, field hockey, and rugby union. Mean age, stature, body mass, and resting systolic and diastolic blood pressure are presented in Table 1. All participants signed an informed-consent document, and the study received institutional ethical approval conforming to the code of ethics of the World Medical Association (Declaration of Helsinki).

Design

A randomized crossover design was used to assess the impact of a brief period of remote IPC on maximal land-based sprint performance with 2 separate conditions, IPC and placebo. All participants undertook a prior control with no treatment. In both placebo and IPC trials, participants were fitted with a blood pressure cuff positioned around the upper thigh, distal to the inguinal fold. For placebo, and IPC data. On their first visit, participants’ age, stature, and body mass were recorded along with a measure of resting blood pressure (Omron RX-3, Kyoto, Japan). Any participants presenting with a blood pressure higher than 140/100 mmHg (systolic/diastolic) were precluded from taking part in the study. These guidelines were in line with ethical approval of the study. Participants then completed 3 maximal sprints through electronic timing gates (Smartspeed, Fusion Sport, Australia) placed at 10-, 20-, and 30-m intervals on an indoor 3G synthetic surface. Each sprint was initiated from a standing start 0.5 m behind the line of the first timing gate. One minute of rest was allowed between sprints, with the fastest of the 3 trials being recorded for analysis. Before the first sprint, participants were taken through a standardized 10-minute warm-up procedure including dynamic stretching routines and culminating in 2 submaximal 30-m runs to habituate them with the sprint track. After the collection of baseline data all participants underwent both placebo and IPC treatments in a randomized fashion.

Placebo. On arrival at the laboratory, participants had their blood pressure measured to screen for any contraindications to the experimental procedure. They were then instructed to adopt a semirecumbent position on a medical plinth with both legs outstretched. A blood pressure cuff (Boso-roid I aneroid sphygmomanometer, Bosch and Son, Germany) was positioned around the upper thigh, distal to the inguinal fold. For placebo treatment the cuff was inflated by hand to 50 mmHg. This light level of inflation (50 mmHg) has been shown to elicit the sensation of pressure around the thigh without preventing blood flow. Each leg was exposed to 5 minutes of pressure followed by 5 minutes of reperfusion for 3 consecutive cycles, eliciting a total treatment time of 30 minutes. During reperfusion the cuff was fitted to the contralateral leg and inflated to 50 mmHg (see Figure 1). During the treatment participants were asked at regular intervals (every 1 min) to confirm they were able to continue with the protocol. Any participant indicating light-headedness, nausea, or discomfort had the pressure cuff removed immediately and was omitted from the study. After the final 5 minutes of reperfusion, participants were supported while they stepped down from the plinth and given a moment to ensure they were steady on their feet before being taken to the sports
hall to commence the 10-minute warm-up as described previously. The time delay between removing the pressure cuff and commencing the warm-up was 5 minutes. **IPC Treatment.** The IPC treatment followed a format identical to that of the placebo protocol except that the blood pressure cuff was inflated to 220 mmHg, which has been shown to elicit ischemia by occluding arterial blood flow to the lower legs.13

**Statistical Analysis**

Data were checked for homogeneity of variance using the Levene test. All results were nonsignificant \( (P < .05) \) and deemed appropriate for parametric analysis. Data were analyzed using SPSS for Windows (PASW Statistics 17.0) and a repeated-measures ANOVA with significance calculated at \( P < .05 \). Due to the practical nature of the investigation, effect sizes were also used. Effect sizes of <0.2, <0.6, <1.2, and >2.0 were considered trivial, small, moderate, and large, respectively.12

**Results**

Table 1 details the physical characteristics of participants included in the study. Table 2 shows sprint times in seconds recorded over 10, 20, and 30 m at baseline and after placebo and IPC treatments. No significant differences were observed between conditions for any sprint-interval distance \( (P > .05) \). Calculated effect sizes were classified as trivial (ES <0.2).

When analyzed by gender, IPC demonstrated a negative stimulus among female participants over 10, 20, and 30 m with effect sizes of 0.27 (small), 0.57 (small), and 0.27 (small) respectively. Figure 2 shows individual variability found within male and female participants after IPC treatment.

**Discussion**

Data collected in the current study suggest that IPC exhibits neither deleterious nor beneficial effects on linear sprinting speed over 30 m in male participants; however, may be detrimental in a female population. Results suggest that athletes may be categorized as responders or nonresponders to the IPC treatment, demonstrated by large individual differences in performance. The negative impact observed on performance in the female cohort was not expected; it provides useful information for practitioners working with female athletes and shows a similar pattern to data obtained using IPC as a recovery tool.11 Knowledge that the use of IPC will not negatively affect single-sprint performance in some male athletes should allow further investigation to focus on its effect in a repeated-sprint model.
IPC has been shown to have many benefits in a medical setting, most notably in protecting the myocardium from infarction caused by prolonged periods of ischemia. More recent research has suggested the treatment to have an effect on exercise performance.6–8 Although the specific mechanism by which IPC exerts a beneficial effect on exercise remains undetermined, 2 potential pathways have been identified in the literature. First, IPC has been shown to increase oxygen and blood flow via a vasodilation response mediated by elevated adenosine levels.4,11 In addition, the treatment has been shown to preserve ATP levels in a canine model.14 This mechanism may explain the beneficial effect of IPC when it precedes high-intensity aerobic exercise.7,8 IPC has been hypothesized to increase work rate in trained cyclists,6 with an enhanced muscle recruitment via activation of a proposed muscle-recruitment reserve.15 The suggested mechanism is a desensitizing of the afferent groups III and IV, which allows an increase in neural drive and force output. When IPC was used in a swimming population, participants were observed to take more strokes to complete an allotted distance after IPC treatment.8 Such changes may suggest a loss of efficiency demonstrated by a decreased distance per stroke, compensated for by an increased stroke count. Our investigation did not assess changes in stride rate or frequency; however, we recognize the potential for further research in this area. We were interested in whether IPC would have an effect on an exercise challenge of relatively short duration that principally relies on the ability to generate force, as is the case in tasks requiring rapid acceleration, such as land-based sprinting.16 Thus, an increased neural drive and increased stride rate induced by IPC could be expected to exert a positive influence on tasks requiring high force output, such as sprinting; however, we saw no beneficial effect in our cohort.

Unlike the “sprint” exercise used to assess the effect of IPC in swimmers (~1 min),8 the exercise challenge in the current study was considerably shorter. Our results suggest that the intensity and/or duration of the exercise challenge was insufficient to invoke any benefit from IPC, especially given that the treatment has been linked to a sparing of ATP.17 In research conducted with amateur but trained cyclists,18 an IPC treatment applied before exercise to exhaustion at 90% of the cyclists’ peak power output had no effect on performance. The deleterious effects of a decline in arterial oxygen pressure and hemoglobin saturation that may be alleviated by IPC are

Table 2  Sprint Times Recorded in Control, Placebo, and Ischemic-Preconditioning (IPC) Trials for 10-, 20-, and 30-m Split Timings

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th></th>
<th>Placebo</th>
<th></th>
<th>IPC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10-m</td>
<td>20-m</td>
<td>30-m</td>
<td>10-m</td>
<td>20-m</td>
</tr>
<tr>
<td>Mean</td>
<td>1.82</td>
<td>3.19</td>
<td>4.51</td>
<td>1.83</td>
<td>3.23</td>
</tr>
<tr>
<td>SD</td>
<td>0.15</td>
<td>0.15</td>
<td>0.25</td>
<td>0.14</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Note: No significant differences were observed between treatment groups.
apparent only at maximal exercise intensities, but not, it would seem, in all athletes.22 The beneficial effects of IPC may therefore only be apparent when intensity and duration of the exercise challenge are within an optimal zone, the limits of which have yet to be elucidated. Activities such as swimming that limit breathing frequency and induce greater levels of arterial hypoxemia may lend themselves to IPC to a greater extent than other non-frequency-controlled forms of exercise such as high-intensity running and sprinting.8

Despite the nonsignificant differences and trivial effect sizes in performance in male participants, there did appear to be a pattern of responders and nonresponders (Figure 2), as shown in previous work.9 Such a pattern may be explained by a number of factors. IPC has been shown to be detrimental to tasks involving a large eccentric component, with a suggested mechanism being hypoxia-induced reductions in muscle-spindle reactivity.11 In addition, thigh circumference and the associated level of occlusion it allows20 along with participants’ individual threshold and perception of discomfort imposed by IPC may have contributed to the individual nature of responses. Some or all of these factors may be important in explaining the deleterious effect of IPC in female participants, as has been shown elsewhere.11 Future research is required to elucidate the determinants of individual responses that may predispose some athletes to the beneficial effects of IPC treatment.

Results from the current study showed neither improvement nor decrement in performance after IPC treatment in male participants. Confounding findings exist in studies assessing the link between restricting blood flow and augmented force production. Previous studies have found force-generating capacity to be reduced during periods of restricted blood flow and attributed the decline to a lack of available oxygen.21 It should be noted, however, that the exercise demand in the aforementioned study was imposed while blood flow was restricted and not after reperfusion, limiting its ecological validity in an applied environment. In the current study, adequate reperfusion time was allowed between the final episode of occlusion and the initiation of sprinting. Other research has shown arterial occlusion to have no significant effect on muscle-force recovery in the plantar flexors.22 In the same study, muscle oxygenation and force-production capacity were found to be only moderately correlated. This observation may have important ramifications when considering the effect of IPC on repeated-sprint ability, in so much as it may confer a benefit in sparing ATP while exerting no negative impact on force production.

A potential reason for the lack of significant findings in the current study may be that IPC and/or the exercise challenge was not severe enough to cause an accumulation of metabolites sufficient to initiate the biochemical cascade associated with IPC.1 Research has shown that an accumulation of metabolites, specifically adenosine, bradykinin, and opioids, may need to reach a critical threshold in order for the beneficial effects of IPC to be realized.4 The occlusion pressure used in the current study was in line with previous studies7 and set at 220 mmHg. As mentioned previously, circumference of the thigh, limb composition, and limb mass have been shown to affect the pressure applied to underlying soft tissue, thereby implying individual differences at the same absolute external pressure.19 Indeed, in previous studies17 peripheral arterial pulses were detected distal to the pressure cuff. Furthermore, even at 250 mmHg of pressure total occlusion has been shown to not be achieved.23 While it has been suggested that higher pressures are more effective than lower pressures in inducing adaptations to training,24 there is evidence that low pressures may be more effective at increasing intramuscular metabolites.25 In future studies care must be taken to ensure that the externally applied pressure is appropriate for the individual and commensurate with the aims of the intervention.

**Practical Applications**

It could be argued that IPC, when administered before land-based sprinting exercise of a duration closer to 1 minute, may have an advantageous effect, as has been shown in research conducted using swimmers.9 Such an improvement, however, may be of limited use to team-sport athletes who rely heavily on their ability to accelerate over short distances frequently throughout a match.10 Further research is required to elucidate whether a beneficial effect of IPC can be realized when it precedes repeated-sprint activity such as has been reported for a number of invasion-type sports, for example, Rugby League.26 If a repeated-sprint enhancement were observed, IPC could be a useful tool to preparing interchange players while on the bench and still able to view the game in which they are to be introduced. Further practical implications are supported by the fact that in the study conducted in a swimming population8 a performance benefit was conferred some 45 minutes after the final period of occlusion. If this response were demonstrated in team-sport players or track and field athletes, IPC could be used as in intervention before athletes commence their warm-up routine.

**Conclusion**

It would appear that, while there is no significant effect of IPC on performance in sprints of short duration (<5 s) performed in a nonfatigued state, individual differences exist in treatment response that require further investigation. In addition, the use of IPC in female populations should be used with caution, as data from the current study suggest a deleterious impact on performance. It is suggested that further investigation focus on the effect of IPC on extended sprint events such as are found in track and field and also repeated-sprint profiles associated with invasion-type sports. Such study may elucidate the threshold duration required for a beneficial effect of IPC and the physiological changes it elicits to be realized.
Acknowledgments

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References


