Effects of 3-day serial sodium bicarbonate loading on performance and physiological parameters during a simulated basketball test in female university players

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Abstract

The aim of this study was to investigate the effect of 3-day serial sodium bicarbonate ingestion on repeated sprint and jump performance. Fifteen female university basketball players (23.3±3.4 years; 173.1±5.8 cm; 65.8±6.3 kg; 23.6±4.9% body fat) ingested 0.4 $g \cdot kg^{-1}$ of body mass of sodium bicarbonate or placebo for 3 days (split in 3 equal daily doses), before completing a simulated basketball exercise. Sprint and circuit times, jump heights, performance decrements and gastrointestinal (GI) side effects were recorded during the test and blood lactate concentration was measured pre- and post-test. Sodium bicarbonate supplementation led to significant decreases in mean sprint times (1.34±0.23 *vs.* 1.70±0.41 s, p=0.008, 95% CI: -0.54 to -0.10 s) and mean circuit times (30.6±2.0 *vs.* 31.3±2.0 s, p=0.044) and significantly greater mean jump height (26.8 (range 25.2-34.2) *vs.* 26.0 (range 25.6-33.6) cm, p=0.013) compared to placebo. Performance decrement was significantly less for sprints with sodium bicarbonate compared to placebo (9.9 (range 3.4-37.0) *vs.* 24.7 (range 4.1-61.3) %, p=0.013), but not different for jumps (13.1±4.5*vs.* 12.5±.3.1%, p=0.321) between conditions. No differences in GI side effects were noted between conditions. Significantly greater post-exercise blood lactate concentrations were measured in the sodium bicarbonate condition compared to the placebo condition (8.2±2.8 *vs.* 6.6±2.4 $mmol.L^{-1}$, p=0.010). This study is the first to show that serial loading of sodium bicarbonate is effective for basketball players to improve repeated sprint and jump performance during competition, or withstand greater training load during practice sessions without any GI side effects.

Key words: sprint, jump, lactate, performance decrement, gastrointestinal.

Introduction

Sodium bicarbonate ($NaHCO_3$) supplementation has been widely studied as a strategy to delay metabolic acidosis in the muscles during high-intensity short duration (<10 min) exercise (McNaughton et al., 2016). Ingestion of $NaHCO_3$ results in a greater concentration of bicarbonate (HCO_3^-) in the blood by 4-8 $mmol.L^{-1}$, which in turn buffers hydrogen (H^+) ions and increases blood alkalosis (Jones et al., 2016). Kemp et al. (2006) suggested that this alkaline environment in the extracellular fluid increased the efflux of H^+ out of the working muscles, hence reducing intracellular metabolic acidosis.

These chemical changes were associated with better performance during several types of high-intensity exercise (e.g., Bishop et al., 2003). In particular, significant improvements in repeated sprint ability (RSA) performance were observed following acute doses of $NaHCO_3$ ranging from 0.3-0.4 $g.kg^{-1}$ body mass (Bishop et al., 2004; Bishop & Claudius, 2005; Afman et al., 2014; Miller et al., 2016). However, the extent of improvement in RSA performance varied in these studies, and some even reported no improvements in specific parameters (Afman et al., 2014; Miller et al., 2016). These discrepancies could be explained by various exercise protocols (Afman et al., 2014), dosage (Douroudos et al, 2006), gastrointestinal problems (Burke & Pyne, 2007) or sub-optimal timings of ingestion/individual variation in response to supplementation (Sparks et al., 2016).

While most studies used laboratory tests to study the effects of $NaHCO_3$on RSA, these are largely influenced by pacing strategy (Billaut et al., 2011) and lack ecological validity (cycling for team sport players, Bishop et al., 2004; Miller et al., 2016). In contrast, Afman et al. (2014) tested the effectiveness of 0.4 $g.kg^{-1}$ body mass $NaHCO_3$ ingestion on the performance of basketball players during a 60-min simulated basketball exercise. The main

limitation of this study was the reliance of limited basketball-specific movement patterns (forward runs/walks, lay-ups and changes of direction). Indeed, basketball incorporates jumps (35 to 43 per match), and high-intensity shuffles (22 to 58 per match) (Matthew & Delextrat, 2009; Narazaki et al., 2009; Delextrat et al., 2015; Scanlan et al., 2015a, 2015b). While the metabolic demands of shuffling is not known, Buchheit (2010) showed that adding jumps to a repeated sprint sequence resulted in greater cardiorespiratory and metabolic demand (+4% oxygen uptake and +0.8 $mmol.L^{-1}$ blood lactate concentration). It is therefore essential to investigate the effects of $NaHCO_3$ in simulated basketball by incorporating repeated sprints, jumps and shuffles. Another discrepancy in the literature is the dose of $NaHCO_3$ used for supplementation. While a dose of 0.3 $g.kg^{-1}$ body mass is usually recommended (Burke & Pyne, 2007), higher doses are likely to lead to greater performance improvements (Douroudos et al., 2006). However, high, acute doses of $NaHCO_3$ could induce gastro-intestinal (GI) complaints (Burke & Pyne, 2007; Afman et al., 2014). Consequently, serial loading (*i.e.* ingesting smaller doses across multiple days before exercise) could be a good alternative to acute loading. Another advantage of serial loading is that $HCO3^-$ levels stay elevated in the blood for longer after the last ingestion, compared to acute loading (McNaughton and Thompson, 2001), which could avoid the large inter-individual variability in response to acute ingestion of $HCO3^-$ recently reported in the literature (McNaughton et al., 2016; Sparks et al., 2016; Gough et al., 2017).

Within this context, the aim of the present study was to investigate the effects of 3-day serial $NaHCO_3$ingestion on repeated sprint and jump ability and physiological parameters during simulated basketball exercise in female collegiate basketball players.

Methods

Participants

Fifteen female university basketball players (23.3 ± 3.4 years; 173.1 ± 5.8 cm; 65.8 ± 6.3 kg; 23.6 ± 4.9% body fat) volunteered to take part in the study. The sample included six guards, five forwards and four centres. At the time of the study, participants were undertaking two 2-h practice sessions and one match weekly. Participants who had used nutritional supplements in the past two months or had any metabolic, endocrine or orthopaedic problems were excluded. Prior to participation, participants were fully informed about all procedures and gave informed written consent. In addition, approval for the study was granted by the local ethical committee (DREC 0413_30).

Procedures

Design and overview

The study used a double-blind, cross-over design. Participants first took part in a preliminary session consisting of anthropometric measurements (height: Harpenden stadiometer, UK, body mass and body fat: Tanita BC 418 MA Segmental Body Composition Analyser, Tokyo, Japan) and familiarisation with the simulated basketball exercise. Subsequently, they performed two test sessions on an indoor basketball court (temperature 20º±2ºC, humidity: 45±4%) at the same time of day to control for circadian variations and one week apart, each preceded by supplementation of either $NaHCO_3$or placebo. In the 24-h before the first session, participants recorded food and fluid consumption in a diary and were required to replicate this diet before the next test session (Hill & Davies, 2012). Participants were requested not to consume any caffeine and/or alcohol 24-h before tests (Lavender and Bird, 1989; Wang et al., 1995; Bishop et al., 2004; Stuart et al., 2005). Although caffeine could

cause withdrawal in regular caffeine consumers, only 6 of the 15 participants were habitual users and reported to have a maximum of two daily cups (less than 300-mg caffeine).

Supplementation

Participants were administered capsules (MyProtein gelatin caps, Cheshire, UK) containing either $NaHCO_3$ (Dr Oetker, Leyland, UK) or calcium carbonate (Sigma-Aldrich Co. LLC., Dorset, UK, Stephens et al., 2002) with a daily dose of 0.4 $g \cdot kg^{-1}$ body mass for three days before testing. Indeed, it has been recommended to use higher quantities than the 0.3 $g \cdot kg^{-1}$ body mass commonly administered, while serial loading avoids the GI disturbances usually reported with such doses ingested acutely (Burke & Pyne, 2007). In addition, capsules were preferred to powder to mask the taste of the substances ingested and allow blinding of the participants to the experimental conditions. Capsules were consumed in three equal amounts throughout the day (during breakfast, lunch and dinner), with the last ingestion at 7pm on the day before the test. During the supplementation period, participants also reported any gastrointestinal (GI) side effects on a 10-point Likert scale (Jeukendrup et al., 2000).

Basketball simulation protocol: the modified Basketball Exercise Stimulation Test (modified BEST)

The BEST was validated by Scanlan et al. (2012, 2014), (Figure 1). We slightly modified this test, designed for men, to better fit the characteristics of female European basketball players (circuits lasting 35-s to account for the lower match activity frequencies in women and longer recovery periods to reflect the different work:rest ratio of 1:4.3 *vs*. 1:3.6 in women *vs*. men, Ben Abdelkrim et al., 2010; Delextrat et al., 2015, and a total number of circuits of 17 to reflect the duration of a quarter in European basketball). Before each test session participants

127 completed a 10-min warm-up which was typical of their normal pre-game routine involving
128 jogging, short high-intensity sprints, lay ups and stretching.
129
130 ----------Figure 1 here: please refer to appendix----------
131
132 ***Outcome measures***
133 During the modified BEST, time to complete the initial sprint of each circuit was recorded
134 with timing gates (Wireless speedtrap 2, Brower Timing Systems, Draper, Utah, USA), and
135 the mean of all sprint times (ST) during all circuits was calculated. Subsequently Ideal Time
136 (IT, s) was calculated as the best average of two sprint efforts (ST2) multiplied by the number
137 of sprint means (Scanlan et al., 2012), and Total Time (TT, s) was calculated as the sum of
138 ST2 plus the 17^{th} ST (due to the odd number of sprints). Circuit times were recorded with a
139 digital stopwatch, and the mean circuit time (s) over all circuits calculated. A jump mat
140 (Ergojump, Globus Inc., Treviso, Italy) was used to record jump height (cm) for every circuit.
141 The jump performed was a countermovement jump with the hands on hips (Buchheit, 2010).
142 Finally, sprint and jump performance decrements (Sprint PD and Jump PD) were calculated
143 by the following equations (Glaister, 2008):
144 Sprint PD (%) = [(TT/IT) x 100) – 100]
145 Jump PD (%) = [100 - (final jump height/Initial jump height) x 100)]
146
147 Fingertip capillary blood samples were taken at rest, prior to the warm-up, as well as
148 immediately on completion of the modified BEST (within the first min), with blood lactate
149 concentration (LA, $mmol \cdot L^{-1}$) measured using a portable analyzer (Lactate Pro, Arkray,
150 Tokyo, Japan).
151

Statistical Analyses

Shapiro-Wilk tests revealed that mean sprint and circuit times, TT, jump PD and LA were normally distributed. Therefore differences in these outcome measures between $NaHCO_3$ and placebo conditions were assessed by Student T-tests for paired samples, and values were expressed as mean±SD with 95% confidence intervals (95%CI). The remaining outcome measures were not normally distributed, and for these measures, non-parametric Wilcoxon rank-sum tests were used to evaluate differences between conditions, and data were expressed as median and range. An alpha level of $p < 0.05$ was accepted as statistically significant. Effect sizes were calculated as Cohen's *d* (parametric data) and *r* (non-parametric data, calculated as $z/\sqrt{n}$), and interpreted as *small* (>0.1), *medium* (>0.3) and *large* (>0.5) (Cohen, 1988; Rosenthal, 1994). Finally, the test-retest reliability of the modified BEST was assessed on 8 participants by the Pearson correlation coefficient (r), reliability coefficient (Mueller & Martorell, 1988), and intraclass correlation coefficient (ICC) for relative reliability and the technical error of measurement (TEM) and coefficient of variation (%CV) for absolute reliability. All statistical analyses were performed on IBM SPSS version 22 software, except TEM (Microsoft Excel).

Results

$NaHCO_3$supplementation resulted in significant decreases in mean sprint times (-0.36 s, t: -3.106, p=0.008, *d*=1.08, 95% CI for the difference: -0.54 to -0.10, Table 1) and mean circuit times (-0.7-s, t:-2.209, p=0.044, *d*=0.39, Table 1). Variables calculated from the mean sprint times averaged every two sprints also showed significant differences between conditions, with lower IT (-1.62 s, z = -2.482, p=0.013, *d*=0.77, Table 1), TT (-3.24 s, t: -3.106 p=0.008, *d*=1.09, 95% CI for the difference: -4.79 to -0.88 s, Table 1), and sprint PD (-14.8%, z = 2.329, p=0.013, *d*=0.79, Table 1) shown in the $NaHCO_3$ condition compared to the placebo

condition. $NaHCO_3$supplementation also resulted in a significantly greater mean jump height compared to placebo (+0.8 cm, z = -2.481, p=0.013, *d*=0.78, Table 1), with no significant difference between conditions in jump PD (-0.6%, t: 2.109, p=0.321, Table 1). Reliability measures for the modified BEST were r = 0.78 to 0.91, R = 0.82 to 0.90, TEM = 0.20 to 0.32, %CV = 3.5 to 5.2, ICC = 0.81 to 0.93.

----------Insert Table 1 here: please refer to appendix ----------

While no significant difference between conditions was shown in pre-exercise LA concentrations (p=0.283), significantly greater post-exercise LA was evident in $NaHCO_3$condition compared to placebo (+1.6-mmol.L^{-1}, t: 2.954, p=0.010, *d*=0.49, 95% CI for the difference: 0.35 to 2.21, Figure 2).

----------Insert Figure 2 here: please refer to appendix ----------

No, or very limited, GI adverse effects were reported by participants, with no significant difference between $NaHCO_3$and placebo (median scores of 1 (range 1-3) *vs.* 1 (range 1-3), respectively, p=0.987).

Discussion

The results from the present study demonstrate that 3-day serial $NaHCO_3$ ingestion improved repeated sprint and jump performance and increased post-exercise LA in female university basketball players. This is the first study to investigate the effect of serial loading of sodium bicarbonate supplementation on basketball-specific performance.

We showed significant improvements in mean sprint and jump performance and TT and IT following $NaHCO_3$ supplementation, with medium to large effect sizes. These results are in accordance with findings from previous studies using short repeated sprint protocols (<10-min, Zajac et al., 2009; Bishop et al., 2004; Ducker et al., 2013). For example, a significant improvement (+5.1%) in total work (kJ) performed on a cycle ergometer during five repeated 6-s sprints was shown by Bishop et al. (2004) following $NaHCO_3$ ingestion in physically active women. Our greater post-exercise LA with $NaHCO_3$ could be explained by the fact that greater sprint speed commonly involves a rise in carbohydrate turnover, which increases lactate production in the muscle and its efflux into the blood (Saraslanidis et al., 2009). This suggests that participants were able to increase their speed thanks to a less acidic intracellular environment brought about by the extracellular buffering of H^+ ions by $HCO3^-$. However, when longer protocols are used, contrasting results are observed (Bishop & Claudius, 2005; Afman et al., 2014). Indeed, a recent study using acute $NaHCO_3$ ingestion pre-exercise showed better 15-m sprint performance during a simulated basketball exercise test in the HCO_3^- group from 45 to 60 min (Afman et al., 2014). In contrast, $NaHCO_3$ ingestion had no significant effect on mean sprint times during a 72-min intermittent team-sport exercise in trained women (Bishop & Claudius, 2005). These contrasting results could be due to the greater contribution of the oxidative system and lower contribution of the glycolytic system in longer exercise protocols, while it cannot be excluded that less than optimal ingestion timings could also be responsible for the absence of significant results. In shorter high-intensity intermittent efforts, the better performance with $NaHCO_3$ ingestion has been linked to increases in blood pH and improvement in *in vivo* muscle buffer capacity (Bishop et al., 2003). Kemp et al. (2006) suggested that metabolic acidosis was reduced after $NaHCO_3$ ingestion, thanks to increased alkalosis in the extracellular fluid, leading to a greater efflux of

226 H^+ out of the muscle. Blood parameters were not measured in the present study, which limits
227 the extent of our understanding of the mechanisms involved.
228
229 The novel aspect of the present study was the incorporation of basketball-specific movement
230 patterns (jumps and lateral shuffles) in our protocol, to replicated more closely the metabolic
231 and cardiovascular demands of basketball (Buchheit, 2010). Present results showed that
232 $NaHCO_3$ supplementation resulted in significant improvements in mean jump height,
233 showing the effectiveness of this nutritional strategy on basketball-specific effort. This
234 finding is crucial as jumps are involved in a lot of technical actions in basketball, such as lay-
235 ups or rebounds, which can be decisive in the outcome of a match (Delextrat et al., 2015).
236 Our findings showed that jump PD was not affected by $NaHCO_3$ ingestion, which is
237 somewhat surprising. One possible explanation is that only sprint, jump and overall circuit
238 performance were measured, which might have encouraged participants to pace themselves
239 in the tasks that were not specifically measured, and hence hindered the positive influence of
240 $NaHCO_3$ on some of the outcome variables.
241
242 Several studies have shown the benefits of serial loading of $NaHCO_3$ (doses ranging from
243 0.3-0.5 $g.kg^{-1}$ body mass), compared to a placebo on high-intensity cycling tests ranging from
244 30-s to 4-min (McNaughton et al., 1999; McNaughton & Thompson, 2001; Douroudos et al.,
245 2006; Driller et al., 2012). The present study is the first to show the benefits of $NaHCO_3$
246 serial loading on repeated sprint and jump exercise. We used a 3-day serial loading of 0.4
247 $g \cdot kg^{-1}$ $NaHCO_3$, split into three equal doses in the three days preceding testing, as
248 recommended by Burke and Pyne (2007). The benefit of serial compared to acute loading is
249 the lower likelihood of adverse GI side effects (Driller et al., 2012), with similar effects on
250 performance observed with both methods in the literature (Mc Naughton & Thompson, 2001;

Driller et al., 2012). Participants in the present study reported no GI distress, suggesting the practical benefits of this loading method. Another advantage of serial *vs.* acute loading of $NaHCO_3$ is the fact that following serial loading, bicarbonate, pH and excess base changes in the blood are maintained after the supplementation has stopped (McNaughton et al., 1999; McNaughton and Thompson, 2001; Douroudos et al., 2006). McNaughton et al. (1999) suggested that the blood may store the extra HCO_3^- provided and use it to improve performance on a subsequent day. This is a major difference to acute loading, where a single dose is taken, but very large inter-individual variations in the time to alkalotic peak of either blood por HCO_3^- (10-180-min) were recently reported, highlighting the need for individual supplementation timings and blood measures (Miller et al., 2016; Sparks et al., 2016; Gough et al., 2017). Finally Driller et al. (2012) suggested a different mechanism of action of serial *vs*. acute loading after showing an improvement in 30-s cycle performance with serial loading of $NaHCO_3$ without any improvement in buffering capacity, through a better perfusion of muscles thanks to the sodium ions (Na^+), leading to improved oxygen delivery (Mitchell et al., 1990). This is an interesting mechanism to consider, and further studies should be conducted combining a control trial along with a placebo.

Factors to be considered when assessing the effectiveness of $NaHCO_3$ ingestion on repeated sprint performance include sex and training status. Women are usually characterised by greater resistance to fatigue (smaller PD) during repeated sprints (Laurent et al., 2010; Mageean et al., 2011). It appears that lower blood pressure, greater oxidative and lower glycolytic capacity, and neuromuscular factors could underpin these responses (Braun & Horton, 2001; Yoon et al., 2007). This greater resistance to fatigue suggests that females might not benefit from buffer systems as much as men. However, our results show that sprint PD was significantly lower in $NaHCO_3$ compared to placebo (9.9 *vs*. 24.7%, medium effect

size), suggesting that women could still benefit from this type of supplementation. Another factor to consider is participants' training status. Indeed, Joyce et al. (2011) compared the effect of acute and serial $NaHCO_3$loading in well-trained swimmers and did not find any significant effect of either strategy on performance. They suggested that this population might already have a well-developed buffering capacity due to the specificity of their training, which may have masked the potential benefits of $NaHCO_3$.

In conclusion, 3-day serial $NaHCO_3$ ingestion enhanced repeated sprint and jump performance during simulated basketball exercise in female collegiate basketball players compared to placebo. These findings were accompanied by greater post-exercise blood lactate concentrations with $NaHCO_3$supplementation and no adverse GI side-effects. Consequently, serial HCO_3^- loading may be an effective strategy administered before competition to increase performance, or before training to withstand greater training loads in female basketball players. Further studies should investigate if these observed benefits translate to basketball exercise conducted across entire match durations, as well as identifying the optimal dose-response of $NaHCO_3$supplementation alone, or combined with other buffers, such as beta-alanine.

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Authors' contribution: AD, JC and AS were involved in the design, SM and LA in the testing, RR and AD in the statistical analysis and all authors contributed to the write-up.

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Table 1. Performance and physiological characteristics during the modified Basketball Exercise Simulated Test (BEST) in the bicarbonate and placebo conditions.

	Sodium bicarbonate	Placebo
	Mean±SD[#]	Mean±SD[#]
Mean sprint time (s)	1.34±0.23**	1.70±0.41
Mean circuit time (s)	30.58±2.03*	31.3±1.96
Mean jump height (cm)	26.8(25.2-34.2)*	26.0(25.6-33.6)
Ideal Sprint Time (s)	10.22(8.81-12.87)*	11.84(9.50-17.01)
Total Sprint Time (s)	12.07±2.06**	15.31±2.66
Sprint performance decrement (%)	9.9(3.4-37.0)*	24.7(4.1-61.3)
Jump height decrement (%)	13.1±4.5	12.5±3.1

[#]: median (range): for non-parametric data (mean jump height and sprint performance decrement)

***: significantly better (shorter time, smaller decrement or greater jump height) than the placebo condition, p<0.05.**

****: significantly better (shorter time, smaller decrement or greater jump height) than the placebo condition, p<0.01.**

Figure captions

Figure 1. The layout of the basketball exercise simulation test (BEST).

Figure 2. Blood lactate concentrations before and immediately on completion of the modified Basketball Exercise Simulated Test (BEST) in the sodium bicarbonate (black) and placebo (black) conditions.

***: significantly different from the placebo condition, $p<0.05$.**

Figure 1. The layout of the basketball exercise simulation test (BEST).

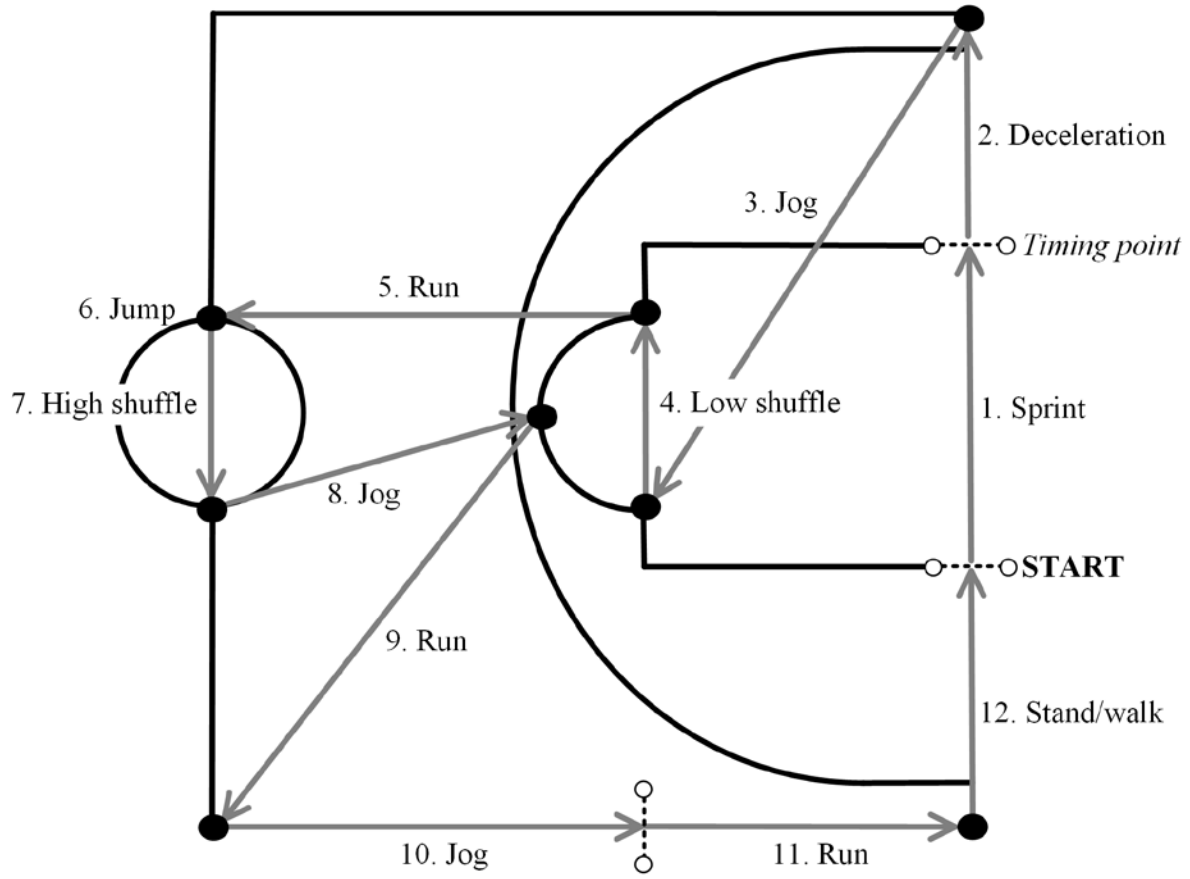
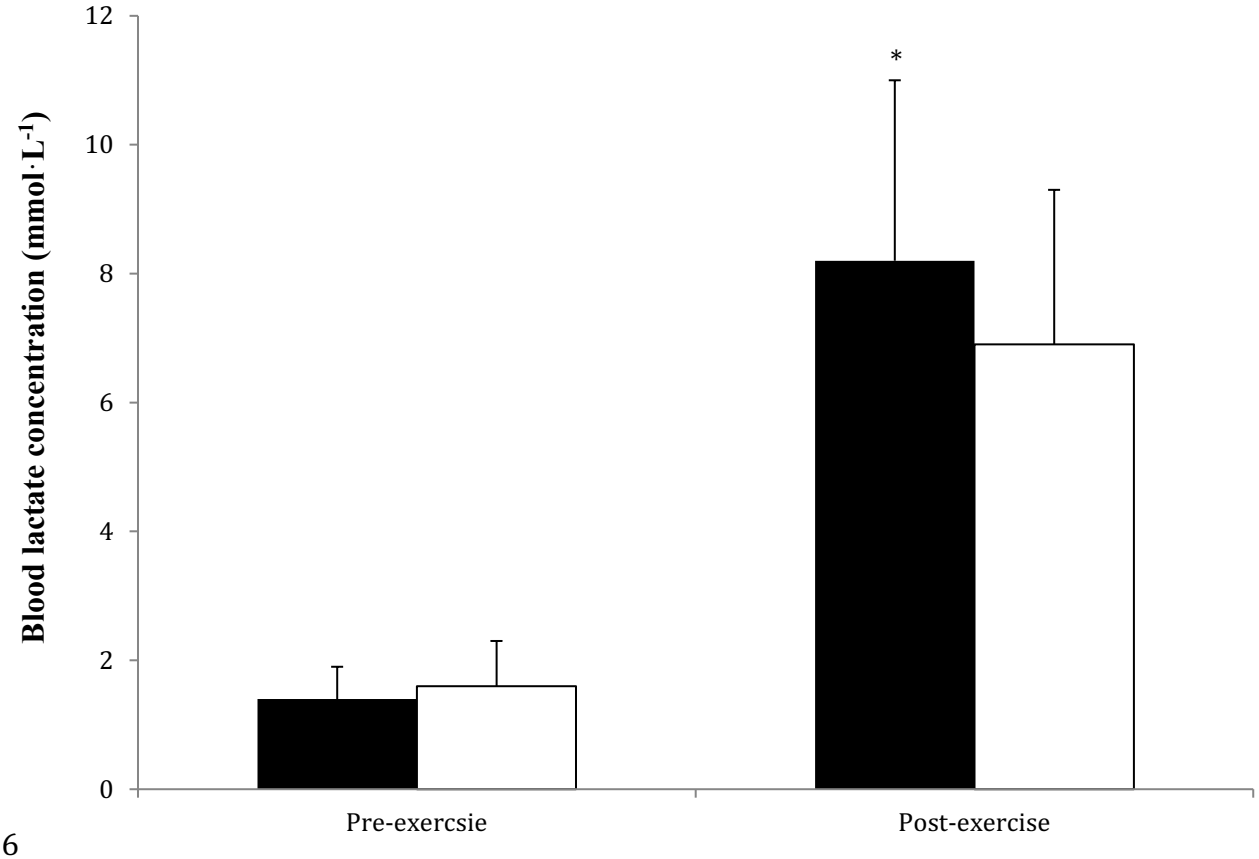


Figure 2. Blood lactate concentrations before and immediately on completion of the modified Basketball Exercise Simulated Test (BEST) in the sodium bicarbonate (black) and placebo (white) conditions.



***: significantly different from the placebo condition, p<0.05.**