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**Article Title:** Influence of Prior Knowledge of Exercise Duration on Pacing Strategies During Game-Based Activities

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Influence of prior knowledge of exercise duration on pacing strategies during game-based activities

Running title: Pacing in small-sided games

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Abstract

**Purpose:** This study investigated the influence of prior knowledge of exercise duration on the pacing strategies employed during game-based activities. **Methods:** Twelve semi-professional team sport athletes (mean ± SD age; 22.8 ± 2.1 yr) participated in this study. Players performed three small-sided games in random order. In one condition (“Control”), players were informed that they would play the small-sided game for 12 minutes and then completed the 12 minute game. In a second condition (“Deception”), players were told that they would play the small-sided game for 6 minutes, but after completing the 6 minute game, they were asked to complete another 6 minutes. In a third condition (“Unknown”), players were not told how long they would be required to play the small-sided game, but the activity was terminated after 12 minutes. Movement was recorded using a GPS unit, sampling at 10 Hz. Post-hoc inspection of video footage was undertaken to count the number of possessions, and the number and quality of disposals. **Results:** Higher initial intensities were observed in the Deception (130.6 ± 3.3 m/min) and Unknown (129.3 ± 2.4 m/min) conditions than the Control condition (123.3 ± 3.4 m/min). Greater amounts of high-speed running occurred during the initial phases of the Deception condition, and more low-speed activity occurred during the Unknown condition. A moderately greater number of total skill involvements occurred in the Unknown condition than the Control condition. **Conclusions:** These findings suggest that during game-based activities, players alter their pacing strategy based upon the anticipated ‘endpoint’ of the exercise bout.

**Key Words:** anticipation, team sport, intermittent exercise, perceived effort, activity profiles
Introduction

Pacing strategies involve the conscious and subconscious variation of exercise intensity, in order to manage the onset of fatigue, and increase the likelihood of completing an activity in a reasonable physiological state. At the beginning of exercise, the pacing strategy employed is subconsciously established based on prior experience completing a similar task within the physiological limits of the body. Afferent sensations are sent from the musculoskeletal and cardiovascular systems to the central nervous system, whereby the pacing strategy is altered (either increased or decreased) based on the brain’s interpretation of the perception of effort.

While pacing strategy is accepted as a key determinant of performance in continuous sports, pacing in intermittent activities has received substantially less attention, although recently, pacing has been suggested to occur in high-intensity, intermittent team sports (e.g. Australian football, rugby league, soccer). Athletes who play the entire match have been shown to exercise at lower intensities than those who are either interchanged during the match, or who are substituted in the final stages of a match. During conditions of thermal stress, or activities comparing lower-skilled competitors with their higher-skilled counterparts, athletes reduce the amount of low-speed activity performed in order to preserve the high-intensity components of competition. Furthermore, during elite women’s soccer match-play, it has recently been shown that when required to perform a greater number of sprints in a repeated-sprint bout, athletes spend greater recovery time in low-intensity activities between each sprint. Collectively, these results suggest a pacing strategy employed by players in an attempt to preserve repeated-sprint and high-intensity exercise performance.

Knowledge of the ‘endpoint’ of exercise is known to influence the pacing strategy employed, and has recently been investigated in intermittent exercise. Waldron et al
and others demonstrated that team sport athletes required to compete for relatively short periods (e.g. substitutes) set a higher initial pacing strategy and exhibited a significantly greater ‘end-spurt’ than athletes required to play the entire match, suggesting that shorter anticipated exercise periods are associated with greater playing intensities. Billaut et al. examined the influence of prior knowledge of sprint number on repeated-sprint exercise performance. Participants performed three repeated-sprint exercise protocols on a cycle ergometer. In one condition (the ‘control’ condition), participants were informed that they would perform ten 6 second sprints (with 24 seconds of rest) and then completed 10 sprints. In a second condition (the ‘deception’ condition), participants were told to perform five sprints, but after the fifth sprint, they were asked to perform an additional five sprints. In a third condition (the ‘unknown’ condition), participants were not told how many sprints they would be performing but were stopped after 10 sprints. There were significant reductions in peak power, mechanical work, and lower-body electromyographic activity in the latter 5 sprints, suggestive of fatigue and reductions in neural drive. More importantly, the initial sprint work, and total work performed during the first 5 sprints of the deception condition were 6.5% greater than the control and unknown conditions, while the total work performed during the unknown condition was 4.0% lower than the other two conditions. In addition, electromyographic activity, particularly during the first 5 sprints, was also higher during exercise of anticipated shorter duration, and lower during exercise of anticipated longer duration. The authors concluded that pacing occurs during repeated-sprint exercise in anticipation of the number of efforts that are included in the bout.

While the study of Billaut et al. has advanced the understanding of pacing during intermittent activity, and the influence of exercise ‘endpoint’ on pacing strategies, it is unclear whether the repeated-sprint protocol employed adequately represents the unpredictable and stochastic nature of high-intensity, intermittent sporting activities. In
addition, while the exercise:rest ratio (1:4) employed in their study is reflective of the average demands of team sport competition, there are periods of repeated high-intensity activity within team sport contests where the exercise:rest ratio is far more demanding (e.g. 3:1).

It is therefore unclear whether the pacing strategies observed during repeated-sprint activity, when players are deceived, or have no knowledge of the exercise ‘endpoint’, reflects the pacing strategies that occur during game-based activities. Moreover, in soccer, it has been suggested that reductions in physical effort (such as covering an opponent’s movement rather than intercepting, or walking rather than jogging) are also associated with changes in skill actions (such as passing rather than dribbling). While the anticipation of exercise ‘endpoint’ may influence the total physical work performed during intermittent activity, based on this evidence it is also possible that players may employ a pacing strategy with respect to the total number of skill involvements in the game (e.g. touches of the ball). With this in mind, the purpose of this study was to investigate the influence of prior knowledge of exercise duration on the pacing strategies employed during game-based activities. Given the wide match-to-match variability in the activity profiles of team sport players, and the large amount of time the ball is out of play during competition, we used a small-sided game controlling for rules, verbal encouragement, pitch size, player numbers, and match duration. Based on the findings of Billaut et al., we hypothesized that players would perform at higher intensities and have greater total involvements with the ball during game-based activities of an anticipated shorter duration, and establish a lower pacing strategy during game-based activities of an anticipated longer duration.
Methods

Subjects

Twelve physically fit men (mean ± SD age, 22.8 ± 2.1 yr; height, 183.7 ± 7.7 cm; body mass, 89.7 ± 8.9 kg; and estimated maximal aerobic power, 54.3 ± 3.2 ml/kg/min) from a semi-professional rugby league team, competing in the Queensland Cup competition, participated in this study. All participants received a clear explanation of the study, including information on the risks and benefits, and written consent was obtained. All experimental procedures were approved by the Institutional Review Board for Human Investigation.

Design

We used a repeated measures experimental design. Testing was conducted over four training sessions. The first session involved familiarization of players with the game-based activity, equipment and procedures. Within one week of the familiarization session, the players performed three small-sided games in random order. Each game was separated by 7 days. In one condition, players were informed that they would play the small-sided game for 12 minutes and then completed the 12 minute game (Control condition). In a second condition, players were told that they would play the small-sided game for 6 minutes, but immediately after completing the 6 minute game, they were asked to complete another 6 minutes, so that the total exercise duration was 12 minutes (Deception condition). In a third condition, players were not told how long they would be required to play the small-sided game, but the activity was terminated after 12 minutes (Unknown condition). Therefore, the total exercise duration was the same for all conditions, although players were provided different information on the expected duration of each small-sided game, prior to each condition.
Procedures

An ‘off-side’ small-sided game was played in each session. Players were separated into 2 teams of 6 players. Each team consisted of 1 forward (second row), 2 adjustables (hooker and halfback), and 3 outside backs (1 fullback, 1 centre, and 1 wing). Players played in the same team for each condition. The small-sided game was played in a standardized (20 m wide x 40 m long) playing area. The ‘off-side’ game permitted players to have 3 ‘plays’ while in possession of the ball. Players were permitted to pass backward or forward (to an ‘off-side’ player). For each play, defending players were required to touch their opponent with two hands. Multiple balls were positioned around the field so that in the case of a ball leaving the field, another was quickly introduced to ensure the game continued. Players were encouraged to provide maximal effort during the small-sided game. The same investigators were present throughout each condition. The pitch dimensions, team numbers, and amount of verbal encouragement were maintained throughout all three conditions.

Activity Profiles

Movement was recorded by a minimaxX GPS unit (Catapult Innovations, Melbourne, Australia) sampling at 10 Hz. The unit was worn in a small vest, on the upper back of the players. The GPS signal provided information on speed, distance, position, and acceleration. The GPS unit also included tri-axial accelerometers and gyroscopes sampling at 100 Hz, to provide information on repeated high-intensity efforts.

Data were categorized into low (0-5 m.s\(^{-1}\)) and high (>5 m.s\(^{-1}\)) movement speed bands.\(^{12}\) The 10 Hz minimaxX units have been shown to have acceptable validity and reliability for measuring high speed (bias = -0.2%; coefficient of variation = 2.0%) and acceleration (bias = -2.1%; coefficient of variation = 1.9%) efforts.\(^{23}\) In addition, prior to performing this study, 12 rugby league players played the identical small-sided game for 8
minutes on two occasions, separated by 6 days. The coefficient of variation for low-speed activity, high-speed running, and total distance were 3.2%, 14.3%, and 4.4%, respectively.

**Perception of Effort**

At the completion of each condition, players provided an overall rating of perceived effort using a CR 1-10 rating of perceived exertion (RPE) scale. As a measure of internal training load, session-RPE was calculated by multiplying the individual RPE by the duration of each game. All players were familiar with the RPE scale, and had previous experience rating the perceived intensity of training drills and small-sided games. Prior to commencing the study we investigated the relationship between heart rate and RPE, and blood lactate concentration and RPE on a subset of subjects during typical training activities. The correlation between training heart rate and training RPE, and training blood lactate concentration and training RPE were 0.89 and 0.86, respectively. A subset of players (n=11) also completed two identical off-season training sessions, performed one week apart, prior to the commencement of the study, to determine test-retest reliability. The coefficient of variation for the RPE scale was 4.0%. Collectively, these results demonstrate that the RPE scale offers an acceptable method of quantifying training intensity for team sport athletes.

**Skill Demands**

A 37 mm digital video camera (Sony, DCR-TRV 950E) was used to track the performance of the players. The game was filmed from an elevated position, approximately 5 m above the field, with the camera positioned end-on to the field. Post-hoc inspection of the footage was undertaken to count the number of possessions (i.e. receives), and the number and quality of disposals. The quality of disposal was determined by coding if the ball-carrier passed to a player who was ‘open’ and the ball went to a team-mate who was in a better position than the passer (i.e. effective pass). An ineffective pass was coded if the pass was
made to a player who was closely marked by an opposition player and the ball was intercepted or turned over, made to an area of the field where no team-mate was positioned, or passed out of the field of play. Total passes represented the sum of effective and ineffective passes, while disposal efficiency was calculated by dividing the number of effective passes by the total number of passes. Total involvements represented the sum of receives, total passes, and errors. Video footage was also coded for the amount of time the ball was in play, and the time that the two teams spent in attack and defence. The coefficient of variation for the coding of skill involvements ranged from 0.2-0.5%. The coefficient of variation for the coding of attack, defence, and ball out-of-play was 0.2%, 0.2, and 0.1%, respectively.

**Statistical Analysis**

Differences in the physical demands were compared using a two-way condition (Control vs. Deception vs. Unknown) x time (First 6 minutes vs. Second 6 minutes) repeated measures ANOVA. Differences in the volume of skill executions among the Control, Deception, and Unknown conditions were compared using a Friedman test. The level of significance was set at p<0.05 and all data are reported as means ± SD. Based on the real-world relevance of the results, two statistical methods were used to determine the meaningfulness of any differences. Firstly, the likelihood that changes in the dependent variables were greater than the smallest worthwhile change was calculated as a small effect size of 0.20 x the between subject standard deviation. Thresholds used for assigning qualitative terms to chances were as follows: <1% almost certainly not; <5% very unlikely; <25% unlikely; <50% possibly not; >50% possibly; >75% likely; >95% very likely; >99% almost certain. The magnitude of difference was considered practically meaningful when the likelihood was ≥75%. Secondly, magnitudes of change in the dependent variables were
assessed using Cohen’s effect size (ES) statistic.\textsuperscript{27} Effect sizes (ES) of 0.20-0.60, 0.61-1.19, and >1.20 were considered small, moderate and large respectively.\textsuperscript{28}

**Results**

Across the 3 conditions, the ball was in play for a total of 2160 seconds (35 minutes, 6 seconds, 97.5%), and out of play for 54 seconds (2.5%). There were no differences in the amount of time spent attacking (1054 seconds, 48.8%) or defending (1052 seconds, 48.7%) between teams, or across conditions.

There was a significant effect of condition and time on the relative intensity of the small-sided games, with higher initial intensities observed in the Deception (130.6 ± 3.3 m/min, ES = 0.62 ± 0.68, 90%, likely) and Unknown (129.3 ± 2.4 m/min, ES = 0.48 ± 0.70, 82%, likely) conditions than the Control condition (123.3 ± 3.4 m/min). Over the course of the small-sided game, greater relative distance was covered in the Deception (ES = 0.63 ± 0.68, 91%, likely) and Unknown (ES = 1.24 ± 0.55, 100%, almost certainly) conditions than the Control condition (Figure 1).

There was a significant effect of condition and time on low-speed activity (Figure 2). Moderately greater (ES = 0.76 ± 0.66, 95%, very likely) low-speed activity was performed in the Unknown condition than the Control condition. No significant differences were found between any of the other conditions for low-speed activity.

There was a significant effect of condition on the high-speed running performed during the small-sided games (Figure 3). While there were no significant time effects, or group x time interactions for high-speed running, the Deception condition had a moderately greater (ES = 1.12 ± 0.59, 99%, almost certainly) amount of high-speed running in the initial period of the game than under the Control condition. Over the course of the game, there was moderately greater (ES = 0.76 ± 0.66, 92%, likely) high-speed running during the Deception
condition than during the Control condition. Of the 12 participants, 7 players performed the most high-speed running during the Deception condition, and 4 players performed the most high-speed running during the Unknown condition. No other significant differences were found between conditions for high-speed running.

There was a significant effect of condition on RPE with the perceived effort greater in the Deception (6.5 ± 0.7 units) condition than the Control (5.3 ± 0.5 units, ES = 0.56 ± 0.69, 81%, likely) and Unknown (5.2 ± 0.5 units, ES = 0.59 ± 0.69, 83%, likely) conditions. The session-RPE for the Deception (78 ± 27 units) condition was greater than the Control (64 ± 21 units, ES = 0.56 ± 0.69, 81%, likely) and Unknown (63 ± 23 units, ES = 0.59 ± 0.69, 83%, likely) conditions.

The volume and quality of skill involvements across the three conditions are shown in Table 1. There were no significant condition or time effects, or condition x time interactions for receives, passes (effective, ineffective, or total), disposal efficiency, errors, or total involvements, although a moderately greater number of total involvements occurred in the Unknown condition than the Control condition (ES = 0.59 ± 0.68, 89, likely). In addition, the Unknown condition had a moderately greater (ES = 0.71 ± 0.67, 93%, likely) number of total skill involvements in the initial period of the game than under the Control condition (Figure 4).

Discussion

This study is the first to investigate the influence of prior knowledge of exercise duration on the pacing strategies employed during game-based activities. Based on the findings of Billaut et al., we hypothesized that players would perform at higher intensities and have greater total involvements with the ball during game-based activities of an anticipated shorter duration, and establish a lower pacing strategy during game-based
activities of an anticipated longer duration. Consistent with this hypothesis, we found greater amounts of high-speed running during the initial phases of the game-based activities in the Deception condition, and more low-speed activity during the game-based activities of Unknown duration. These findings suggest that during game-based activities, athletes alter their pacing strategy based upon the anticipated ‘endpoint’ of the exercise bout.

Players performed more high-speed running during game-based activities of an anticipated shorter duration, with the initial high-speed running intensity also greater during the Deception condition. We also found a higher RPE during game-based activities of an anticipated shorter duration. These findings are consistent with the hypothesis that a greater conscious perception of effort occurs when high-speed running intensity is greater. Of the 12 participants, 7 players performed the most high-speed running during the Deception condition, and 4 players performed the most high-speed running during the Unknown condition. These findings suggest that the instructions on expected game time provided to these players prior to game-based activities could be individualized to maximize physical performance.

During the Deception condition, players commenced the exercise bout at a higher running intensity than the Control condition, and maintained high-speed running across the duration of the game. A reduction in low-speed activity was likely responsible for the maintenance of high-speed running during the Deception condition. Conversely, during the Unknown condition, the initial high-speed running activity of players was lower than the Deception condition, with players maintaining this high-speed intensity across the course of the game. However, the reduced high-speed running activity in the Unknown condition, relative to the Deception condition occurred alongside greater low-speed activity, resulting in comparable relative intensities between the Deception and Unknown conditions. Clearly,
these findings suggest that different individual pacing strategies can be employed to achieve a similar overall playing intensity.

Prior experience with a task has been shown to be important for setting an appropriate pacing strategy. While all players were familiar with the high-intensity game employed in this study, it is possible that some players were more familiar with the activity than others. The finding of greater high-speed running for the Unknown condition in 33% of players is in contrast to others and might suggest that these players (1) set a higher pacing strategy in the knowledge that they could down-regulate intensity if required, or (2) perceived that the task posed a low threat to physiological homeostasis, and set their pacing strategy accordingly. Finally, it is plausible that factors other than the instructions provided by the investigators influenced the pacing strategies observed during the Unknown condition. Prior knowledge of the usual duration of training sessions, along with the typical duration of high-intensity training games, may have resulted in some players predicting the likely ‘endpoint’ of exercise, and setting a higher overall pacing strategy.

There were no significant differences between conditions for the number of receives, passes (effective, ineffective, or total), or errors, although a moderately greater number of total involvements occurred in the Unknown condition than the Control condition. In addition, the Unknown condition had a moderately greater number of total skill involvements in the initial period of the game than under the Control condition. Although we assessed the volume and quality of skill executions, no attempt was made to quantify changes in the tactical strategies employed across the three experimental conditions. It has been suggested that team sport athletes alter their behaviours during match-play based on their perception of a homeostatic disturbance, with athletes consciously choosing to walk rather than jog, or pass rather than dribble, in order to avoid unsustainable elevations in physical discomfort at a premature stage of a match. The greater amount of low-speed activity, coupled with the
moderately greater number of total skill involvements (including passes and effective passes), suggests that during the Unknown condition, players increased the amount of walking, jogging, and passing, rather than running with the ball. This down-regulation of effort during the game-based activity of Unknown duration was most likely initiated to avoid fatigue resulting in premature cessation of exercise.\textsuperscript{1,16,29}

While this study provides important information on the regulation of physical effort during high-intensity intermittent game-based activities, it is not without limitations. Firstly, our data collection was limited to one semi-professional team and four training sessions. Due to the inherent game-to-game variability in activity profiles, particularly in high-speed running,\textsuperscript{21} this study may have benefitted from a larger sample size, and multiple trials for each condition. Secondly, the finding that 33\% of our players performed more high-speed running in the Unknown condition is somewhat unexpected. Given the relatively short duration of the small-sided games it is likely that the present results are not representative of the pacing strategies employed during longer bouts of high-intensity activity. We used a 12 minute small-sided game because this is a common exercise duration employed by coaches in the training environment. Furthermore, pacing strategies have been shown to alter during exercise of much shorter durations.\textsuperscript{4} However, we cannot discount the possibility that more consistent group results may have been observed if we used a game-based activity of longer duration. Notwithstanding these limitations, the present results extend our understanding of exercise ‘endpoint’ on the pacing strategies employed during game-based activities.

In conclusion, this study investigated the influence of prior knowledge of exercise duration on the pacing strategies employed during game-based activities. We found greater amounts of high-speed running during the initial phases of game-based activities of an anticipated shorter duration, and more low-speed activity during the game-based activities of
anticipated longer duration. These findings suggest that during game-based activities, athletes alter their pacing strategy based upon the anticipated ‘endpoint’ of the exercise bout.

**Practical Applications**

Higher playing intensities were observed when players were either deceived about the duration of game time, or when they were given no specific information on game duration. These results suggest that providing players with specific information on the minutes they are likely to play is more likely to result in a lower pacing strategy than if players are provided with less specific information. However, the total number of skill involvements was greatest when game durations were Unknown. In terms of skill involvements, providing players with minimal information on the likely game duration could increase their total number of skill involvements, although it may come at the expense of high-speed running. Finally, of the 12 players, 58% performed the most high-speed running during the Deception condition, and 33% performed the most high-speed running during the Unknown condition. The instructions on expected game time provided to these players prior to game-based activities could be individualized to maximize physical performance and skill involvements.
References


Influence of Prior Knowledge of Exercise Duration on Pacing Strategies During Game-Based Activities

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Figure 1. Relative distance covered during the Control, Deception, and Unknown game-based activities.

Plot ‘A’ shows the relative distance covered during the first and second half of the 12 minute game. Plot ‘B’ shows the overall relative distance covered across the entire 12 minute game.

* Significant (p<0.05) effect of condition. # Significant (p<0.05) effect of time. a = moderate effect size. b = large effect size. Data are mean ± SD.
Figure 2. Low-speed activity during the Control, Deception, and Unknown game-based activities.

Plot ‘A’ shows the distance covered at low-speeds during the first and second half of the 12 minute game. Plot ‘B’ shows the overall low-speed activity across the entire 12 minute game. * Significant (p<0.05) effect of condition. # Significant (p<0.05) effect of time. a = moderate effect size. Data are mean ± SD.
Figure 3. Relative distance covered in high-speed running during the Control, Deception, and Unknown game-based activities.

Plot ‘A’ shows the relative distance covered at high-speeds during the first and second half of the 12 minute game. Plot ‘B’ shows the overall relative distance covered in high-speed running across the entire 12 minute game. * Significant (p<0.05) effect of condition. a = moderate effect size. Data are mean ± SD.
Figure 4. Total skill involvements during the Control, Deception, and Unknown game-based activities.

Plot ‘A’ shows the total number of skill involvements during the first and second half of the 12 minute game. Plot ‘B’ shows the overall number of total skill involvements across the entire 12 minute game. $a =$ moderate effect size. Data are mean $\pm SD$. 
**Table 1.** Volume and quality of skill involvements during the Control, Deception, and Unknown game-based activities.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Deception</th>
<th>Unknown</th>
<th>Effect Size</th>
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</thead>
<tbody>
<tr>
<td>Receives (no.)</td>
<td>14.8 ± 1.5</td>
<td>14.8 ± 2.3</td>
<td>18.1 ± 1.7</td>
<td>0.01 to 0.56</td>
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<td>Effective Passes (no.)</td>
<td>14.8 ± 6.6</td>
<td>15.4 ± 2.1</td>
<td>17.9 ± 1.8</td>
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<td>Ineffective Passes (no.)</td>
<td>1.2 ± 0.3</td>
<td>1.1 ± 0.3</td>
<td>1.7 ± 0.4</td>
<td>0.08 to 0.56</td>
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<tr>
<td>Total Passes (no.)</td>
<td>15.9 ± 1.7</td>
<td>16.5 ± 2.2</td>
<td>19.6 ± 1.9</td>
<td>0.09 to 0.58</td>
</tr>
<tr>
<td>Disposal Efficiency (%)</td>
<td>93.1 ± 2.0</td>
<td>93.4 ± 1.6</td>
<td>91.1 ± 2.1</td>
<td>0.06 to 0.36</td>
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<tr>
<td>Errors (no.)</td>
<td>1.5 ± 0.3</td>
<td>1.8 ± 0.4</td>
<td>2.1 ± 0.3</td>
<td>0.19 to 0.57</td>
</tr>
<tr>
<td>Total Involvements (no.)</td>
<td>31.1 ± 3.1</td>
<td>32.0 ± 4.4</td>
<td>38.0 ± 3.5</td>
<td>0.07 to 0.59</td>
</tr>
</tbody>
</table>

Data are mean ± SD