**Manuscript Title:** Knowledge of task end-point influences pacing and performance during simulated rugby league match-play

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**Abstract**

**Purpose:** To examine the influence of knowledge of exercise duration on pacing and performance during simulated rugby league match-play. **Methods:** Thirteen male university rugby players completed three simulated rugby league matches (RLMSP-i) on separate days in a random order. In a control trial, participants were informed that they would be performing 2 x 23 min bouts (separated by 20 min) of the RLMSP-i (CON). In a second trial, participants were informed that they would be performing 1 x 23 min bout of the protocol, but were then asked to perform another 23 min bout (DEC). In a third trial, participants were not informed of the exercise duration and performed 2 x 23 min bouts (UN). **Results:** Distance covered and high intensity running was higher in CON (4813 ± 167 m; 26 ± 4.1 m·min$^{-1}$) than DEC (4764 ± 112 m; 25.2 ± 2.8 m·min$^{-1}$) and UN (4744 ± 131 m; 24.4 m·min$^{-1}$). Compared to CON, high intensity running and peak speed was typically higher for DEC in bout 1 and lower in bout 2 of the RLMSP-i, whilst UN was generally lower throughout. Similarly, DEC resulted in an increased heart rate, blood lactate and rating of perceived exertion than CON in bout 1, whereas these variables were lower throughout the protocol in UN. **Conclusions:** Pacing and performance during simulated rugby league match-play is dependent on an accurate understanding of the exercise end-point. Applied practitioners should consider informing players of their likely exercise duration to maximise running.

**Key Words:** Deception. Team Sports. Fatigue. Rating of Perceived Exertion.

## Introduction

Pacing, defined as the distribution of energy expenditure during athletic competition, has been well-defined in continuous 'closed-loop' exercise[1]. Indeed, an athlete's pacing strategy is fundamental to success in events where maintaining the highest average speed is the goal[2]. However, in team sports that comprise different actions such as standing, walking, jogging, sprinting and tackling, pacing is less well understood.

In rugby league, the amount and type of work that athletes complete appears to be related to playing position[3], playing standard[4], nature of the opposition[5], playing home or away[5] and whether the player is playing for the whole match or part of it[6]. Furthermore, running intensity fluctuates during a match more stochastically than 'continuous' exercise[7], but in a predictable enough manner such that common traits are apparent. That is, there is often a gradual reduction in total and high-intensity running over the course of a game, and a period of repeated high-intensity efforts is followed by a transient reduction in energy expenditure relative to the match average[8].

Accordingly, it appears that several different variables influence an athlete's movement characteristics such that they 'pace' their efforts during exercise. However, the precise way in which athletes do this is unclear. During continuous exercise, it is thought that athletes regulate their exercise in accordance with the principle of teleoanticipation[9], whereby work is distributed based on a complex interplay between a feed-forward template developed for the exercise and feedback from peripheral and central physiological systems. For this model of exercise regulation, the athlete must know the exercise duration to adopt an appropriate pacing strategy that enables safe completion[10,11]. Interestingly, deception of the exercise end-point affects performance during both continuous exercise[12] and repeated sprints[13], such that more work is completed in the early stages of exercise.

However, only one study has studied this phenomenon when athletes are required to perform intermittent activity specific to team sports. Gabbett et al.[14] examined the performance effects of accurately informing participants of the duration of a small sided game (~12 min) compared to deceiving them (players were informed that it would last for 6 min). They reported that players covered greater distance when they were deceived about the exercise duration (130.6 $m \cdot min^{-1}$) rather than informed of it accurately (123.3 $m \cdot min^{-1}$), whilst they also performed ~2 $m \cdot min^{-1}$ more high-intensity running in the initial 6 min of the game. Thus, an athlete's pacing strategy is seemingly influenced by a manipulated understanding of exercise duration in stochastic and intermittent sports. However, Gabbett and colleagues' use of short duration training activities limits the extrapolation of their findings to match play, given that an individual's pacing strategy is clearly influenced by exercise duration[1]. Furthermore, match play includes physical contacts and collisions, which are known to add a significant physiological cost to exercise[15], and influence work done via running[16]. Finally, Gabbett et al.[14] did not include any physiological measurements, thus mechanistic insight on changes in running during team sports are limited. Whilst this work provided valuable information on pacing during training, it remains unclear whether an individual's understanding of exercise duration influences work during activity more closely aligned to the demands of rugby. Accordingly, the aim of this study was to examine the influence of knowledge of exercise duration on pacing strategy and physiological responses during simulated rugby league match play. It was hypothesised that participants would perform optimally (i.e. increase their running speed and distance) when they were accurately informed of the exercise duration.

## Methods

Participants

After approval from the Faculty of Life Sciences Research Ethics Committee, 13 male university standard rugby league and union players volunteered to participate in the study (age = 22 ± 3 years, stature = 1.77 ± 0.02 m, body mass = 82.7 ± 8.0 kg, predicted $\dot{V}O_{2max}$ = 54 ± 4 $ml \cdot kg^{-1} \cdot min^{-1}$). All participants provided written informed consent and completed a health questionnaire before starting the study. Participants engaged in rugby related training for approximately 4 hours and participated in one competitive match per week.

Design

Participants completed four visits in a repeated measures design. On the initial visit, participants completed a multi-stage fitness test[17] before familiarisation with an isokinetic dynamometer and the rugby league movement simulation protocol (RLMSP-i). For the RLMSP-i, familiarisation required the participants to complete two cycles of activity. In the following three visits, in a random order, participants completed the same RLMSP-i where they were: a) accurately informed of the exercise duration (CON); b) deceived of the exercise duration (DEC); c) not told how long the exercise duration would be (UN). Each visit was separated by between three and seven days and performed at the same time of day. Participants were instructed to refrain from strenuous exercise in the 48 h before each trial, and completed a food diary in the 48 h before the first visit, which they were then asked to replicate before subsequent trials.

Methodology

On an artificial 3G playing surface, participants completed the RLMSP-i, which accurately replicates the average speed, distance and playing time of elite interchange rugby league players[18]. Before the protocol, participants performed a 10 min standardised warm-up consisting of varied running intensities and dynamic stretches. Environmental conditions were recorded for each trial. CON, DEC and UN were performed at a similar temperature (25.1˚C ± 4.7˚C, 24.1˚C ± 2.4˚C, 22.6˚C ± 2.9˚C) and relative humidity (32.2% ± 10%, 30.3% ± 7.1%, 33.8% ± 7.9%).

The simulation protocol consists of 2 x 23 min bouts of intermittent exercise separated by 20 min. Running alone, participants were instructed to perform various activities in time with an audio signal from a CD, with distances demarcated by cones positioned on a 28.5 m track, details for which have been described in detail elsewhere[18]. Before the protocol, participants were given standardised instructions that were specific to each trial. Briefly, in CON, participants were instructed that they would be performing 2 x 23 min exercise bouts. In DEC, participants were told that they would be performing 1 x 23 min bout, but upon completion of this bout were asked to complete a further 23 min. In UN, participants were told that they would be exercising for an unknown period of time up to 80 min, but again performed 2 x 23 min bouts. Thus, participants completed the same exercise protocol in each trial, but received different instructions on the exercise duration. In each trial a clock was made visible to the participants to gauge the duration of the exercise bout. Participants were informed that they could view this clock at any point to gauge their remaining exercise time. However, we did not prompt participants to view the clock, or their remaining time, throughout the protocol.

During the protocol, movement speeds and heart rate (HR) were recorded using a global positioning system (GPS) positioned in a custom made vest positioned between the participant's scapulae (MinimaxX S5, firmware 6.75, Catapult Innovations, Melbourne, Australia). Total distance, high-intensity running (> 14 $km \cdot h^{-1}$) sprint speed and average HR were calculated and analysed per quartile of each 23 min exercise bout (~ 5.75 min). These variables possess adequate reliability to detect a meaningful change in performance (CV% = 1.1-2.9%[18]). Satellite availability during experimental trials was 12-19. A rating of perceived exertion (RPE) was provided at the end of each quartile, while blood lactate was recorded from a fingertip capillary blood sample (Lactate Pro, Arkray, Kyoto, Japan) ~ 5 min before the protocol and immediately after each 23 min bout. Measured RPE was subsequently used to calculate a 'hazard score'[19], which is a product of multiplying the given RPE by the remaining duration of exercise (for example, an RPE measured half way through the protocol was multiplied by 0.5).

Peak isokinetic knee extension torque at 60 $deg \cdot s^{-1}$ (Biodex Multi-Joint Sytem 3, Biodex Medical, USA) was also recorded ~ 1 h before and ~ 30 min after exercise, with the peak value from five repetitions of the dominant limb taken for analysis. Participants were restrained to minimise any extraneous movement, with the dynamometer lever arm positioned at the participants' malleoli. The mass of the limb was recorded to allow for gravitational correction of recorded torque, and participants received visual feedback of their torque production to encourage maximal effort. The reliability of peak torque measured in our laboratory is CV% = 4.2%.

Statistical analysis

All data are presented as mean ± standard deviation (SD). Changes in movement, physiological and perceptual responses to the RLMSP-i were analysed using qualitative inferences based on effect sizes and associated 90% confidence intervals[20]. Effects were classified as small (mean difference greater than 0.3 x pooled SD), moderate (0.9 x pooled SD) or large (1.6 x pooled SD), with the following thresholds for likelihood based on confidence intervals; <0.5% most unlikely, 0.5-5% very unlikely, 5-25% unlikely, 25-75% possibly, 75-95% likely, 95-99.5% very likely, >99.5% most likely. Statements based on the size and likelihood of an observed effect are made in italics for clarity, whilst differences are presented as the change; ±90% confidence interval.

**Results**

There was no trial order effect observed for the measured dependent variables (effects were either *trivial* or *unclear*).

Movement characteristics during the RMPSP-i

From the first to the second exercise bout, there was a *most likely moderate* decline in distance covered in CON (-2.6; ± 1 $m \cdot min^{-1}$), with a *most likely large* and *very large* decline in UN (-3.8; ± 1.3 $m \cdot min^{-1}$) and DEC (-4.0; ± 1.4 $m \cdot min^{-1}$), respectively. For high intensity running, there was a *most likely small, moderate*, and *large* decline between bouts for CON (-2.5 ; ±0.7 $m \cdot min^{-1}$), UN (-2.7; ±1.1 $m \cdot min^{-1}$) and DEC (-3.4; ±1.1 $m \cdot min^{-1}$), respectively.

There was a *possible small* decrease in the total distance covered in the RLMSP-i during the DEC trial compared to CON (-49.1; ± 56.9 m), but no difference between CON and UN or DEC and UN (Figure 1a). However, for high intensity running, the difference between CON and UN was *possibly moderate* (-1.6; ±2.0 $m \cdot min^{-1}$), and *possibly small* (-0.8; ±1.2 $m \cdot min^{-1}$) between CON and DEC and DEC and UN, respectively (Figure 1).

**********Insert Figure 1 about here***********

Specific meaningful differences in pacing during the RLMSP-i are shown in Figure 2. Most notably, DEC resulted in participants covering a *moderately lower* (-3.4; ±2.2 m·min$^{-1}$) distance in the initial quartile of the second bout of exercise, and generally less high intensity running over the second bout (but most notably in the final quartile). In the UN trial, there was a general *small* decline in distance covered and high intensity running compared to CON in each quartile, with a larger difference observed in the final quartile of the protocol (-3.2; ± 2.6 m·min$^{-1}$). The peak speed that participants achieved in each quartile was *possibly* higher in DEC for bout 1, but lower for bout 2, particularly in the final quartile (-1.3; ±1 km·h$^{-1}$). Much like HIR, UN resulted in a *possible* reduction in peak speed across quartiles, but especially in the final quartile of the protocol (-1.8; ±1.1 km·h$^{-1}$).

**********Insert Figure 2 about here***********

## Physiological and perceptual responses

Heart rate and RPE was *possibly* higher in in the final quartile of bout 1 in DEC compared to CON (3.8; ±5.8 b·min$^{-1}$). In UN, heart rate was *possibly* lower than CON in the final quartile of bout 2 (-4.1; ±7.4 b·min$^{-1}$), whilst RPE was *likely* lower for most of the quartiles of the RLMSP-i. The calculated hazard score was *likely/very likely* lower in all quartiles of the protocol in UN compared to CON. DEC resulted in a *possible* and *very likely* increase in the hazard score in quartiles 3 (0.2; ±0.4 au) and 4 (0.4; ±0.3 au) of bout 1, respectively (see Table 1).

At the end of bout 1, blood lactate concentration was *possibly* higher in DEC compared to CON (1; ±1 mmol·l$^{-1}$), and lower in UN compared to CON (1.8; ±1.4 mmol·l$^{-1}$). At the end of bout

2, there was a *likely moderately* higher blood lactate concentration in CON compared to UN and DEC (Table 1). *Small* decrements in isokinetic peak torque of the knee extensors after the RLMSP-i were apparent in the CON and DEC trials only (Table 2).

**********Insert Tables 1 and 2 about here***********

**Discussion**

This is the first study to examine the influence of knowledge of the task end-point on pacing during exercise designed to simulate the match demands of a contact team sport. Our data indicate that an individual's understanding of the exercise duration is a key determinant of pacing strategy and performance during this type of exercise. Specifically, participants covered the greatest distance and performed more high intensity running when they were correctly informed of their exercise duration, whilst the opposite was true when participants were unaware of the exercise duration. With regard to the pacing strategy adopted during the RLMSP-i, participants covered less distance, performed less high intensity running and attained a lower peak sprint speed in most bout quartiles compared to when they were correctly informed of the exercise duration. Contemporaneous changes in the physiological and perceptual responses to movement tended to reflect the change in external load observed in each condition.

The general reduction in exercise intensity in UN was also associated with a reduced RPE and blood lactate concentration throughout the RLMSP-i compared to CON. Our observation that individuals voluntarily lower their exercise intensity and physiological exertion when they are unaware of the exercise duration is consistent with previous research in continuous[21] and repeated-sprint exercise[13]. This down regulation of pacing strategy is thought to be the consequence of participants maintaining a metabolic reserve to reach the unknown exercise end-point without premature exhaustion or severe disturbance to homeostasis[22]. According to contemporary pacing theories[9,10,11,23,24], individuals are thought to undertake exercise with a pre-set template of their exercise intensity, which is a function of their understanding of the exercise duration and previous experience. However, during exercise this template undergoes dynamic alterations based on feedback to the central nervous system from peripheral structures regarding the amount of homeostatic disturbance[25]. The sum of these afferent signals is thought to be reflected in an individual's RPE, which can then be continually compared to the 'template' RPE set before exercise[11]. As such, it is unsurprising that participants adopted a lower RPE – and indeed attained an average RPE of only 14 at the end of the RLMSP-i - in the face of an unknown exercise duration in the present study. We propose that this would ensure a sufficient metabolic reserve was maintained to complete upcoming unknown events with minimal risk of a severe disturbance to homeostasis. Indeed, that participants' isokinetic muscle function remained unchanged after completing the RLMSP-i in the UN condition indicates minimal fatigue was present. This seemingly resulted in a sub-optimal performance given that participants completed 1.4% less distance, 6.2% less high-intensity running, and produced a maximal sprint that was 4.8% lower than when they were correctly informed of the exercise duration.

Further evidence that participants maintained a significant metabolic reserve in the UN trial is the lack of an end-spurt. That is, participants failed to increase their running speed towards the end of the protocol, as is commonly observed during several types of self-paced exercise[26]. An end-spurt results from a reduced uncertainty of the remaining exercise duration, and thus no metabolic reserve needs to be maintained and motor unit recruitment and RPE increases with a reduced threat of homeostatic failure[11]. This relationship between exercise intensity, RPE and remaining exercise time has been described using a 'hazard score', which is the product of remaining exercise duration and momentary RPE[19]. Whilst in events of known duration individuals are willing to increase exercise intensity when the end-point approaches (as the hazard score will be low – see Table 1), it seems that when participants are unaware of the exercise duration during simulated team sport exercise, the possibility of an extended exercise duration results in a hazard score which cannot be calculated and thus an end-spurt does not occur. Our results support this assertion, as the calculated hazard score was consistently lower in the UN trial.

Interestingly, an end-spurt was evident in the CON and DEC trials, but this occurred at different times. More specifically, participants increased their peak speed in the final quartile of bout 1 in DEC (the time they believed the protocol would finish), whereas this occurred at the end of bout 2 in CON. The end-spurt in DEC coincided with participants exhibiting a higher hazard score than CON, presumably because the deception created a mismatch between the perceived and actual time remaining. Participants also seemed to increase their exercise intensity across bout 1 in DEC compared to CON, whilst this condition produced the highest peak sprint speed of all trials. However, much like UN, deception of the exercise end-point seemed to result in a pacing strategy that was sub-optimal across the two exercise bouts of the RLMSP-i, as peak speed was reduced in bout 2, and participants completed 1.1% and 4% less distance covered and high-intensity running, respectively.

Whilst our findings are consistent with others who have examined knowledge of the exercise end-point on endurance[21,26,27], repeated-sprint performance[13] and repeated maximal voluntary contractions[28], they are different to the only study to investigate the effect of knowledge of task end-point in team sport athletes. Gabbett et al.[14] reported that rugby players covered a greater total distance and high intensity running during small-sided games when they were deceived compared to when the duration of exercise was known. Participants also increased relative distance during the unknown compared to known condition, although the unknown condition comprised more low intensity activity. The reason for the discrepant findings of Gabbett et al.[14] are not clear, although it was proposed that their participants were likely to have a prior knowledge of the usual duration of training games, and thus an 'unknown' and 'deception' trial might have had limited influence on participants' pacing strategy. Furthermore, the shorter exercise duration (~6-12 min) employed by Gabbett et al.[14] might have encouraged a different pacing strategy to that observed in the present study. Indeed, shorter exercise durations are typically associated with an 'all-out' pacing strategy[1], rather than the even pacing observed here.

Practical Applications

For the first time we provide evidence that contact team sport players regulate their movement activity based on an understanding of the match end-point, adopting a pacing strategy similar to other forms of closed-looped exercise. We believe this has potential applied implications for team sports athletes. Most importantly, to maximise running, team sport players who have the potential to be interchanged should be informed of their likely exercise duration. This might include telling an interchange player how long their bout will be (or indeed how many bouts they are likely to be involved with) or accurately informing players that they will be playing a whole match. Where possible, practitioners might also consider providing players with regular information on how far away they are from being interchanged to allow an end-spurt in exercise intensity to occur. Interestingly, if increased exercise intensity in a single bout is desirable, this can potentially be achieved by telling the athlete they are exercising for a shorter duration.

However, this is likely to have implications for any subsequent exercise bout if they are to be repeatedly interchanged.

The present study did not include an analysis of participants' contact intensity, which is likely to have important implications for pacing during rugby league matches[16]. As such, future studies may wish to examine the influence of knowledge of task end-point on individuals pacing of contact intensity in addition to energy expenditure associated with running. Furthermore, the implications of knowledge of task end-point on pacing during repeated training sessions warrants attention, as this study would indicate that intensity - and therefore potential training stimulus - can be altered based on an individual's understanding of the exercise duration. Finally, further mechanistic insight into the changes in performance observed with altered pacing strategies is required. Future studies may wish to investigate electromyographic activity or voluntary activation to determine motor unit recruitment patterns associated with altered pacing.

## Conclusions

This study has demonstrated that knowledge of task end-point influences performance, pacing and physiological and perceptual responses to simulated rugby league match-play. To ensure an optimal pacing strategy, players should be accurately informed of their likely exercise duration.

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**Conflict of Interest:** None.

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## Figure Legends

**Figure 1.** Total (a) and high intensity (b) distance over the whole RLMSP-i

**Figure 2.** Changes in (a) distance covered, (b) High intensity distance, and (c) Peak speed during the RLMSP-i. Q = quartile for a given bout. ▲Denotes a meaningful difference between CON and UN. ○Denotes a meaningful difference between CON and DEC.

**Table 1.** Physiological and perceptual measurements throughout the RLMSP-i during different trials. Data are mean ± SD.

| | | Bout 1 | | | | Bout 2 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| Heart Rate (b·min$^{-1}$) | **CON** | 159 ± 24 | 167 ± 23 | 169 ± 21 | 167 ± 22 | 160 ± 23 | 166 ± 21 | 166 ± 21 | 167 ± 22 |
| | **UN** | 158 ± 11 | 166 ± 11 | 166 ± 11 | 165 ± 12 | 159 ± 10 | 164 ± 12 | 163 ± 12 | 162 ± 13* |
| | **DEC** | 162 ± 15 | 171 ± 12 | 171 ± 12 | 172 ± 12* | 160 ± 11 | 166 ± 12 | 167 ± 13 | 167 ± 12 |
| RPE (6-20) | **CON** | 12.5 ± 1.2 | 14 ± 1.8 | 14.7 ± 1.5 | 15.4 ± 1.6 | 12.9 ± 1.4 | 13.8 ± 1.5 | 14.6 ± 1.8 | 15.3 ± 1.6 |
| | **UN** | 11.8 ± 1.6# | 13 ± 1.7# | 13.8 ± 1.8# | 14.1 ± 1.5# | 12.3 ± 1.2* | 13.2 ± 1.7* | 13.7 ± 1.8# | 14 ± 1.5# |
| | **DEC** | 12.6 ± 1.6 | 14 ± 1.2 | 15.1 ± 1.6* | 16.2 ± 1.6* | 12.8 ± 2.1 | 14.1 ± 2* | 14.7 ± 1.6 | 14.7 ± 1.8* |
| Hazard Score (AU) | **CON** | 10.97 ± 1.1 | 10.56 ± 1.4 | 9.23 ± 1.0 | 7.73 ± 0.8 | 4.85 ± 0.5 | 3.46 ± 0.4 | 1.84 ± 0.2 | 0 ± 0 |
| | **UN** | 10.37 ± 1.5# | 9.81 ± 1.3^ | 8.65 ± 1.1# | 7.08 ± 0.8# | 4.62 ± 0.5# | 3.31 ± 0.5# | 1.72 ± 0.2# | 0 ± 0 |
| | **DEC** | 11.04 ± 1.4 | 10.5 ± 0.9 | 9.47 ± 1.0* | 8.12 ± 0.8^ | 4.82 ± 0.8 | 3.54 ± 0.5 | 1.85 ± 0.2 | 0 ± 0 |
| Blood Lactate (mmol·l$^{-1}$) | **CON** | 3 ± 1.6 | - | - | 4.7 ± 3.2 | - | - | - | 5.6 ± 3.9 |
| | **UN** | 2.6 ± 0.8 | - | - | 2.9 ± 1.3# | - | - | - | 2.8 ± 1.7# |
| | **DEC** | 2.7 ± 1 | - | - | 5.7 ± 2.6* | - | - | - | 3 ± 1.8# |

Q= bout quartile. CON = control trial, UN = unknown duration trial and DEC = deception trial. * *possible* difference to CON, # *likely* difference to CON, ^ *very likely* difference to CON. All effects were *small*, with the exception of post measurements of blood lactate compared to CON, and the hazard score in bout 4 in UN compared to CON, which were *moderate*.

**Table 2.** Changes in isokinetic peak torque at 60 deg·s$^{-1}$ in the knee extensors

| | **Pre** | **Post** |
|---|---|---|
| **CON (N·m)** | 239.3 ± 48.6 | 224.2 ± 50.7* |
| **UN (N·m)** | 236.3 ± 49.8 | 235.2 ± 51.9 |
| **DEC (N·m)** | 236.9 ± 37.2 | 225.6 ± 40.4[#] |

* *possible small* difference to Pre. [#] *likely small* difference to Pre.