Different psychophysiological responses to a high-intensity repetition session performed alone or in a group by elite middle-distance runners.

Journal:	*European Journal of Sports Science*
Manuscript ID	TEJS-2018-0652.R2
Manuscript Type:	Original Paper
Keywords:	Training, Behavior, Endurance, Performance

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Abstract

Internal training load refers to the degree of disturbance in psychophysiological homeostasis provoked by a training session and has been traditionally measured through session-RPE, which is the product of the session Rate of Perceived Exertion (RPE) and the duration. External training load refers to the actual physical work completed, and depends on session volume, intensity, frequency and density. Drafting, which is achieved by running closely behind another runner has been demonstrated to reduce the energy cost of running at a fixed speed and to improve performance. Therefore, it is hypothesized that psychophysiological responses might reflect different levels of internal load if training is performed individually or collectively. 16 elite middle-distance runners performed two high-intensity training sessions consisting of 4 repetitions of 500 m separated by 3 minutes of active recovery. Sessions were performed individually and collectively. Times for each repetition, RPE, core affect (valence and felt arousal) and blood lactate concentrations [BLa] were measured after each repetition. Main time effect was significant and increased across repetitions for [BLa] and RPE ($p < 0.001$), and decreased for valence ($p = 0.001$). Main group effect was significant and values were higher when training individually for [BLa] ($p = 0.003$) and RPE ($p = 0.001$), and lower for valence ($p = 0.001$). No differential responses were found between conditions in terms of repeat time or felt arousal. Findings demonstrate that elite middle-distance athletes running collectively display lower levels of internal training load compared to running alone, despite external training load being similar.

Key words: Training, behavior, endurance, performance.

Introduction

The goal of physical training is to evoke an adaptive response to an imposed stimulus, and not necessarily to achieve maximal levels of performance within the individual training session itself (Mujika, 2017). Achieving the optimal stimulus required to achieve the desired adaptive response requires precise control and regulation of exercise intensity in order to allow careful manipulation of both internal and external loading. The external load refers to an objective measurement of the work an athlete produces during training or competition (such as distance covered or times achieved), whilst the internal load refers to the disturbance in homeostasis of the physiological (e.g. cardiovascular, respiratory and metabolic) and psychological processes provoked by a training session. It has been suggested that internal load is the primary stimulus to adaptation in endurance training (Mujika, 2017), and is therefore considered the most important feature of a training session.

Internal training load imposed by a single session can be quantified through calculation of a session-RPE score (Foster et al., 1998) which is the product of the session Rate of Perceived Exertion (RPE) and the duration. However, recently a three-dimensional framework of centrally regulated and goal directed exercise behaviour was proposed, which emphasises the dynamic and complex interplay of sensory, affective, and cognitive processes that underpin perceived fatigability (Venhorst, Micklewright & Noakes, 2018). This framework more comprehensively accounted for perception-thinking-action coupling in response to psychophysiological distress than the traditional Gestalt concept of perceived exertion (Venhorst, Micklewright & Noakes, 2018). Accordingly, internal training load too may be better understood by assessing sensory, affective and motivational components separately, rather than solely relying on an un-decomposable Gestalt phenomenon. It is conceivable that several factors can differentially alter perceived exertion, valence and arousal at the same absolute exercise intensity, thereby leading to varying degrees of internal training for the same external training load. For example, a high-intensity repetition running session may be expected to generate different performance and perceptual responses in athletes with similar endurance capabilities depending on whether the session is completed individually or collectively. Recent field and laboratory studies have emphasized the importance of the presence of other individuals on pacing behaviour, psychophysiological responses and performance. Competition against virtual opponents during cycle time trials have been shown to provoke the selection of faster initial speeds (Konings, Schoenmakers, Walker & Hettinga, 2016), subsequently causing greater disruption of physiological homeostasis despite unchanged values of perceived exertion (Konings, Parkinson, Zigdewind & Hettinga, 2018). This effect of the presence of other individuals has been suggested to be a hardwired human tendency to interact with others (Renfree, Crivoi do Carmo, Martin & Peters, 2015). Moreover, Edwards et al. (2018) found that external verbal encouragement improved performance and motivation to exercise on self-paced endurance and sprint exercise. Reduced perceived exertion has been suggested to be a result of a reduction in the cognitive work required to make complex pacing decisions (Renfree et al., 2015). Another psychological state implicated in the regulation of exercise intensity that has been demonstrated to be influenced by performance relative to others is core affect. In particular, a more negative affective state appears to be induced by poor performance relative to other individuals (Jones et al., 2015; Venhorst, Micklewright & Noakes, 2018)

In addition to altered perceptual responses, performing running training sessions within a group may also reduce the energetic costs, and thereby internal load for the same external load (speed and volume). Drafting, which is achieved by running closely behind another runner has been demonstrated to reduce the energy cost of running at a fixed speed (Davies, 1980; Kyle, 1979; Pugh, 1970; Pugh, 1971). Additionally, Zouhall et al. (2015) reported that 10 elite middle and long-distance runners benefited from drafting behind another runner, improving their 3000 m run performance achieved during a non-drafting condition, despite no change in energetic expenditure. However, blood lactate concentrations were higher after the non-drafted 3000 m run than after the drafted 3000 m run. Furthermore, athletes perceived the non-drafted 3000 m run to be more strenuous than the drafted 3000 m run.

As previously described, determinants of pacing behaviour and performance have been studied extensively in both actual and simulated competitive situations. However, less information is available on these variables during training sessions which often involve athletes performing multiple runs over the same distance in either an interval or repetition format. Knowledge of the relationships between these variables would be of practical significance to coaches, as there is more opportunity to modify the environment in which training sessions are performed. For example, a coach has the opportunity to prescribe training sessions to be performed individually or collectively with other athletes if there is evidence that one format results in higher or lower levels of internal load than the other. This would seem to be particularly the case in high-intensity repetition training where achieving a specific programmed internal training load is considered a difficult task, given that small variations of external training load have been demonstrated to produce substantial differences in internal training load (Billat, 2001). Furthermore, this kind of training is extremely important for middle-distance runners because it represents the only way of reproducing competition paces (Billat, 2001). Thus, according to the previously mentioned studies which focused on the benefits of drafting in running (Davies, 1980; Kyle, 1979; Pugh, 1970; Pugh, 1971; Zouhall et al., 2015), it is hypothesised that elite middle-distance runners conducting high-intensity running repetitions collectively would accumulate lower levels of blood lactate and experience lower levels of perceived exertion than when conducting the same repetitions individually. A greater degree of peripheral physiological disruption in the individual condition may also be related to a more negative affective state (Renfree et al., 2012). Therefore, the aim of the present study was to assess the differential responses in metabolic and perceptual variables to running when alone or in a group during high-intensity repetitions performed by elite middle-distance runners.

Materials and methods

Participants

Sixteen elite middle-distance runners (Male: n =13, Female: n =3; age =24 ± 4 years old) were recruited from a professional middle-distance running group. Runners are currently active at national or international level and 10 of them have been selected by their national federation to compete in international events. Runners regularly compete at the 1500 m event, and the mean 1500m best performance during the 12 months preceding the study was 229 ± 7.53 s for males, and 270 ± 8.78 s for females. Participants completed 7.1 ± 1.2 training sessions per week and have been systematically training for 7.1 ± 3 years. All participants provided written informed consent prior to participation in the experimental procedures, which was approved by the ethics committee at the Isabel I de Castilla University, and conducted in accordance with the declaration of Helsinki.

Design

A repeated measures experimental AB/BA counterbalanced crossover design was employed involving assessment of performance, metabolic and psychological variables during two sessions of high-intensity repetition running. Each session consisted of 4 repetitions of 500 m runs separated by 3 minutes of recovery. Sessions were performed either individually or collectively whereby athletes adopted different positions within the group during each repetition.

Procedures

Participants were instructed to arrive for testing in a rested (having avoided strenuous exercise in the previous 48 hours), fully hydrated state and having refrained from eating for at least 3 hours. Accordingly, they were asked to prepare their training and diet for 48 h prior to both high-intensity running sessions in a way that resembled their routine before an important race or high-intensity running session. This session was completed twice 7 days apart on a synthetic 400 m athletics running track. Weather conditions were similar on both occasions (sunny, wind speed average 1.11 ± 0.7 m/s, 24 ± 0.8 ºC and 31 ± 6.1 % of humidity). Both sessions were performed at 11 a. m. to control for diurnal variations. At the first training session, male participants were divided into 2 groups with 7 and 6 male participants completing the first session individually and collectively, respectively.

All female participants completed the first session collectively. Male groups were formed in consultation with the athletes' coach, and athletes were allocated to groups based on the coach's subjective rating of current performance level. One week later, participants completed the session in the other condition (individually or collectively).

Before experimental trials, participants completed a standardised warm-up of 15 minutes easy running and 10 minutes of dynamic stretching and drills as part of their usual training routine. In each training session, participants completed four consecutive 500 m repetitions with 3 minutes of active recovery (standing during the measurement period and walking for 100 meters) between each. Repetitions were hand timed twice to the nearest tenth of second by the coach and a researcher and the average between both measures was therefore calculated 'in situ'. The four fastest athletes in each male group (based on recent 1500m performances) were allocated to lead one of the four repetitions during the group running session. While the four strongest runners shared the pacemaker role, the remaining runners had to stay in contact with the rest of the group. In contrast, the female group had to share this role among just three athletes. Accordingly, they were assisted with the inclusion of one experienced male pacemaker across the four repetitions. It also increased the number of the runners who ran collectively in this group. Thus, the effect of the different size between the female group and the male groups was slightly reduced by the inclusion of a pacemaker in the female group. Realistic session time goals were agreed by athletes in consultation with their coach. The coach set a maximum running pace for each repetition for each athlete according to his knowledge of their current condition and performance level for the individual running session and a maximum running pace for the whole group for each repetition for the collective running session taking into consideration the level of performance of each runner who formed the group and that the group had to keep united throughout the whole session. The pacesetter and the participants were allowed to wear their own watches to assist with pace judgement. During each session and immediately after each repetition, participants provided subjective ratings of perceived exertion, valence, and felt activation using single-item scales. Ratings of felt arousal were also provided prior to the first repetition. Capillary blood samples for blood lactate [BLa] analysis was taken within the first minute post each repetition. Due to the reduced amount of time available to collect and analyse the capillary blood samples for multiple athletes between group running repetitions, two researchers and two lactate analysers were required to perform this task.

Measures during exercise

Ratings of perceived exertion (RPE)

The 15-point (6 – 20) Borg scale (Borg, 1982) with the indicator terms 'easy' and 'hard' was used to record RPE. Participants provided a whole number response, and the scale was 'anchored' by explaining that a score of 20 should equate to a previous memory of absolute exhaustion. They were directly asked to report 'how hard, heavy and strenuous this repetition was' (Pageaux, 2016). Therefore, participants were instructed to report the mental sense of effort caused by the task.

Core affect

According to recent recommendations (Ekkekakis, 2013), a detailed three-tiered justification process has been described for measurement selection in the assessment of dynamic changes in core affective state during prolonged endurance exercise (Venhorst, Mickelwright & Noakes, 2018). Accordingly, participants were asked to approximate dynamic changes in valence from -5 ('very bad') to 0 ('neutral') to +5 ('very good') after each 500 m repetition using the 11-point Feeling Scale (FS, Hardy & Rejesky, 1989). Felt arousal was approximated just before the first 500 m repetition and after each 500 m repetition using the 6-point Felt Arousal Scale (FAS, Svebak & Murgatroyd, 1985) from 1 ('low activation') to 6 ('high activation'). Participants were encouraged to use decimals when rating felt arousal.

Blood analysis

Post repetition lactate concentrations were determined from capillarised blood samples taken from the earlobe using the Lactate Scout analyser (Senslab, Leipzig, Germany). This analyser has shown high levels of intra analyser reliability (r =0.910), inter analyser reliability (r = 951), between portable analyser accuracy (r =0.967) and portable analyser versus laboratory analyser accuracy (r =0.837) (Tanner, Fuller & Ross, 2010).

Statistical analyses

Statistical analyses were performed using the Statistical Package for the Social Sciences 24.0 (IBM, Armonk, NY, USA). Data were checked for normality of distribution, equality of variances and assumption of sphericity as appropriate. When the sphericity assumption was violated, the Greenhouse-Geisser correction was employed. A paired samples t-test and the determination of the corresponding effect size (ES) using Cohen's d were used to examine differences in average time for the 500 m repetitions between experimental conditions. ES were considered to be either small (0.21 – 0.50), moderate (0.51 – 0.80) or large (>0.80) (Cohen, 1988). Two-way (group x repetitions) repeated measures ANOVAs were used to examine the differences in performance, expressed as the percentage of the average of the four 500 m repetitions speed, and to examine differences in the blood lactate concentrations, perceived exertion, valence and felt arousal. Where appropriate post hoc pairwise comparisons were made with Bonferroni correction. Effect sizes were calculated using partial eta-squared. All data are presented as mean and standard deviation (mean ± SD).

Results

Average 500 m repetition time was 76.9 ± 5.07 s in individual sessions, and 77.38 ± 5.34 s in collective sessions, respectively ($t = 2.02$, $p = 0.058$, $d = 0.091$).

Neither the group x time interaction effect for the 500 m repetitions time ($F_{3,45} = 1.898$, $p = 0.189$, $\eta_p^2 = 0.112$) nor main group effect were significant. However, there was a main significant time effect ($F_{3,45} = 4.320$, $p = 0.014$, $\eta_p^2 = 0.224$), with the third repetition being slower than the second ($p = 0.009$) (Figure 1A).

The group x time interaction effect for blood lactate concentrations wasn't significant ($F_{3,45} = 0.661$, $p = 0.581$, $\eta_p^2 = 0.042$). Blood lactate concentrations were greater in the individual trial than during the group trial. The main group effect was significant ($F_{1,15} = 12.65$, $p = 0.003$, $\eta_p^2 = 0.457$). Furthermore, blood lactate concentrations increased across the session. The main time effect was significant ($F_{1.84,27.63} = 83.98$, p

<0.001, η_p^2 =0.848). Blood lactate concentrations differed (p <0.001) between all repetitions other than the third and fourth (p =0.443) (Figure 1B)

The group x time interaction effect for perceived exertion wasn't significant ($F_{3,45}$ =1.758, p =0.169, η_p^2 =0.105). Perceived exertion ratings were greater in the individual trial than during the group trial. The main group effect was significant ($F_{1,15}$ =19.05, p =0.001, η_p^2 =0.560). Perceived exertion increased across the session and differences were significant between all repetitions. The main time effect was significant ($F_{2.02,30.30}$ =46.85, p <0.001, η_p^2 =0.757) (Figure 1C).

The group x time interaction effect for valence wasn't significant ($F_{3,45}$ =2.569, p =0.066, η_p^2 =0.146). Valence ratings were lower in the individual trial than during the group trial. The main group effect was significant ($F_{1,15}$ =15.69, p =0.001, η_p^2 =0.511). Valence became more negative as the session progressed. The main time effect was significant ($F_{1.98,29.65}$ =8.62, p =0.001, η_p^2 =0.365) (Figure 1D).

The group x time interaction effect for felt arousal wasn't significant ($F_{4,60}$ =0.350, p =0.843, η_p^2 =0.023). The main group effect wasn't significant ($F_{1,15}$ =0.14, p = 0.713, η_p^2 =0.009). The main time effect wasn't significant ($F_{2.02,30.30}$ =0.94, p =0.444, η_p^2 =0.059).

*FIGURE 1 HERE

Discussion

The findings of the current study demonstrate the existence of differences in metabolic strain, and perceptual responses during high-intensity repetition running conducted at similar levels of performance either individually or collectively by a group of elite middle-distance runners. We found that although overall performance and pacing behaviour across the training session did not differ between conditions, the sessions performed collectively resulted in lower post-repetition blood lactate concentrations, reduced perceived exertion, and more positive affective state. A noticeable feature of this study was the high-performance level of the experimental participants, and the 'real world' scenario, whereby data were collected during training sessions of the type routinely performed during the pre-competition phase of preparation. Another key feature of this study is that it investigated the psychophysiological responses to training stimuli, which may be under-researched given a typically greater interest in competition effects.

Overall performance did not differ between conditions, nor did pacing behaviour across the entire session. This may be considered slightly surprising given that research performed in the laboratory has demonstrated that the presence of other (virtual) competitors influences performance, pacing, and the decline in muscle force experienced during 4 km cycle time trials (Konings et al., 2016). However, Konings et al. (2018) also found that these changes occurred despite similar ratings of perceived exertion, whereas we found performance was similar despite lower perceived exertion in the collective condition. Nonetheless, those studies were not conducted in a real training environment and did not assess the influence of a group, which should be taken into consideration when interpreting and comparing their results with this study. It may be the case that we found no significant performance difference between conditions because the participants had agreed on goal times prior to the training sessions, and we speculate that if they had been blinded to feedback during repetitions then we may have observed faster repetitions in the collective condition, but at similar perceived exertion values. The lower blood lactate concentrations in the collective condition indicate that the degree of metabolic strain was lower. A plausible explanation for these findings is that in the collective condition athletes benefitted from the energetic savings conferred by drafting. Pugh (1970) estimated that the energy cost of overcoming air resistance in track running is about 8% of total energy cost at 6 m/s and observed that the relation between VO_2 and speed was linear in the treadmill and curvilinear in the track. The same author (1971) also found that running 1m behind another runner virtually eliminated air resistance and reduced VO_2 by 6.5% at 6 m/s. At the speeds athletes were running in this study, the VO_2 reduction might be likely higher than the mentioned ~6.5%. Indeed, our results are in general agreement with those of Zouhal et al. (2015) who reported an improvement in 3km running performance accompanied by reduced perceived exertion and blood lactate concentrations when runners were able to follow a pacemaker. However, in contrast with our study and although trials were conducted on a track, participants had to carry a portable VO_2 analyser during the trials, they were drafting for just 66.6% of the whole distance, and no training partners were participating in the trials (just the pacemakers). These circumstances are therefore very different to those of a real collective training environment. Thus, no other study has analysed the influence of running in a group while external load has remained stable in both conditions and the change of the internal load was determined and quantified by the increment of perceived exertion, valence and blood lactate concentrations. In this sense, the change of the energy cost observed in this study seems to be not fully explained by drafting effects but also by other aspects like the need of setting a pre-agreed stable pace. For example, Lander, Butterly & Edwards (2009) found that participants who were required to row 5000 m at a constant submaximal rating of perceived exertion produced lower levels of blood lactate concentrations than at an enforced constant submaximal pace equivalent to the mean power output of the other condition.

A key finding of the present study was that affective valence was more positive after each of the repetitions in the collective condition. Given that internal training load was higher in the individual condition (evidenced by higher RPE and blood lactate concentration), a potential explanation for this observation is that the more negative affective valence in the individual condition resulted from a greater degree of peripheral physiological disruption (Renfree et al. 2012).

However, felt arousal remained similar throughout the session and did not differ between conditions. Although the reasons for this are not entirely clear, we suggest that the collaborative rather than the competitive nature of the exercise protocol may have had some impact on the results. Rather than attempting to 'beat' opponents, participants were working towards pre-agreed goal levels of performance, and did so by sharing the energetically costly leading positions between themselves. In this sense, Kilpatrick et al. (2007) found that untrained subjects modified their felt arousal depending on the intensity of the exercise and that it slightly variated across time but not at every stage of the exercise bout. In contrast with that research, it is important to emphasize that the participants in this study were very well trained with extensive experience of high-intensity training sessions of this type, which may account for the similar arousal levels reported in each condition. This was also a routinely performed training session rather than a performance directed time trial or race. Accordingly, it was proposed that unconscious calculations continuously control emotion arousal and induce the choice of optimal intensity in order that the optimum exercise intensity can be maintained until the end point and, therefore, experienced athletes are trained to control it in a more sophisticated way (Renfree & Casado, 2018).

Two limitations have to be acknowledged in this study. Blood lactate concentrations could not be assessed in duplicate due to the reduced amount of time available to measure a considerable number of athletes after each repetition. Secondly, the runners who displayed superior performance levels during previous competitions were not allowed to set a maximum intensity during the repetitions in order to preserve group structure. Thus, maximal performance was not assessed in this study.

Given that these observations were made in a training session rather than a performance test, the findings that valence and perceived exertion differed between conditions have potentially important implications for training prescription. Our findings would therefore imply that whether a high-intensity repetition session is performed individually or collectively would influence the internal training load (as measure by session-RPE), which may not only be determined by perceived exertion and training time but also valence.

Practical implications.

Given that an effective training program is characterized by low levels of monotony (Foster, 1998), which is a measure of day to day variability in training load, then this implies that consideration should be given to whether sessions should be performed alone or as part of a group, as manipulation of this factor has potential to alter monotony through its influence on individual session-RPE score. Accordingly, coaches are encouraged to elaborate the design of training programming accounting for these variables through setting programmed higher intensity when the high-intensity repetition session is conducted collectively than individually. In this manner, session-RPE would keep stable in both sessions.

Acknowledgements.

Authors gratefully acknowledge the outstanding contributions of the coach and the athletes who participated in this study. Authors also thank the colleagues who reviewed draft versions of this article and provided useful suggestions and advice for revision.

Disclosure statement.

Authors disclose the absence of professional relationships with companies or manufacturers who would benefit from the results of the present study.

Fundings.

Authors report the absence of any kind of funding for the development of the present study.

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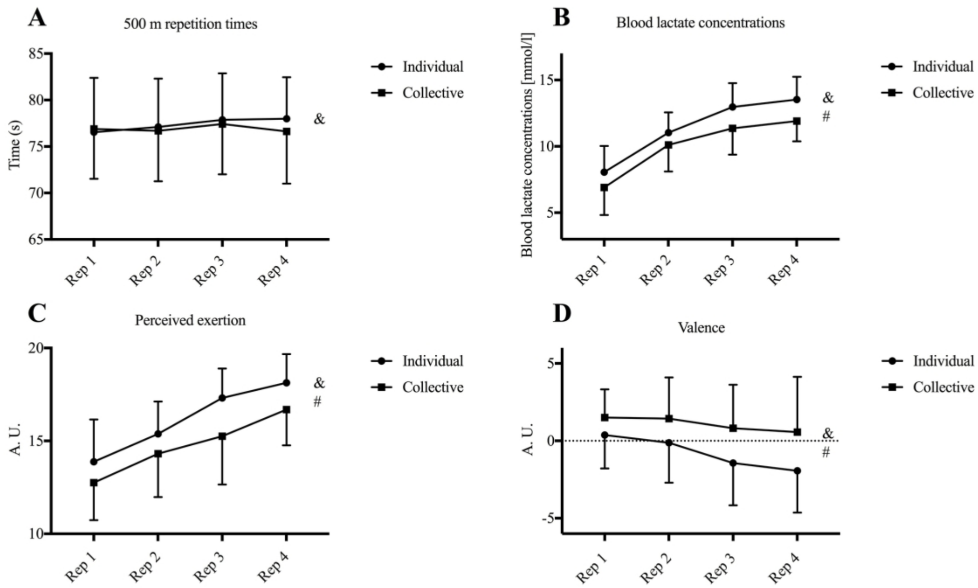
Figure legends

Figure 1. A. Times recorded for each repetition. $p = 0.009$ between the second and the third repetition. B. Blood lactate concentrations after each repetition. $p < 0.001$ between repetitions other than the third and the fourth. C. Perceived exertion after each repetition. $p < 0.001$ between all repetitions. D. Valence after each repetition. $p = 0.001$ between repetitions. Rep =repetition. & =main time effect; # =main group effect; Significance is accepted at $\alpha < 0.05$



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