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Abstract

Malone, S and Collins, K. Relationship between individualized training impulse and aerobic fitness measures in Hurling players across a training period. *J Strength Cond Res* 30(11): 3140–3145, 2016—The current study examined the association between individual internal training load (individualized training impulse, iTRIMP) and aerobic fitness variables in male hurling players. Twenty hurling players (age, 25.5 ± 3.2 years; height, 178.9 ± 3.2 cm; body mass, 78.5 ± 4.5 kg) performed treadmill testing for $\dot{V}O_2$max, running economy (RE), and the speed at blood lactate concentrations of 2 mmol·L^{-1} (S2) and 4 mmol·L^{-1} (S4) on separate occasions before and after an 8-week training period. The Yo-Yo intermittent recovery (Yo-YoIR1, Yo-YoIR2) test performance were also assessed before and after the training period. Individualized training impulse was calculated using the blood lactate and heart rate profile of each individual player and was further assessed for each training session across the intervention period (n = 990). The results showed that iTRIMP had large to very large association with the percentage improvements in $\dot{V}O_2$max ($r = 0.77$; $p = 0.002$; 95% confidence interval [CI], 0.38–0.93, very large), RE ($r = 0.78$; $p = 0.002$; 95% CI, 0.40–0.93; very large), S2 ($r = 0.64$; $p = 0.004$; 95% CI, from 0.25 to 0.85; large), S4 ($r = 0.78$; $p = 0.003$; 95% CI, 0.45–0.85; very large), Yo-YoIR1 ($r = 0.69$; $p = 0.003$; 95% CI, 0.45–0.92; large), and Yo-YoIR2 ($r = 0.60$; $p = 0.005$; 95% CI, 0.45–0.92; large) performance. The study shows that iTRIMP is a means of quantifying training load in team sports and can be used to prescribe training for the maintenance or improvement of aerobic fitness during the competitive season with strong relationships seen between weekly iTRIMP measures and improvements in aerobic fitness measures.

Key Words heart rate, blood lactate, aerobic power, anaerobic threshold, dose-response

Introduction

Training outcomes are the result of the interplay of many variables imposed on athletes across the training process (5,21). The training adaptation that accrues is individualized and related to the magnitude of the prescribed training load (TL) (2,25,26,31). As a result, the quantification of the individual response to a prescribed TL is vital to profile training-related adaptive responses (2,28). Recently, a number of studies have examined the individualized responses to training using heart rate (HR)–based methods. Manzi et al. (26) have shown that with a fully individualized approach to TL using individualized training impulse (iTRIMP), it was possible to accurately track fitness improvements during aerobic training sessions in endurance athletes. The results reported showed that after an 8-week period of training for endurance athletes, the mean weekly iTRIMP (arbitrary unit) significantly correlated with changes in velocity at lactate threshold (*vLT*; $r = 0.87$) and velocity at the onset of blood lactate accumulation (*vOBLA*; $r = 0.72$). The mean weekly iTRIMP also showed significant correlations with changes in 5,000 m ($r = -0.77$) and 10,000 m ($r = -0.82$) running performance within this cohort.

Team sports players are often submitted to group-based training sessions aiming to develop team fitness and technical-tactical skills (21). The potential for differential training responses from grouped-based training may present challenges. The importance of training individualization is well known, which is considered as favorable for optimal performance development in team-based sports (3,31). Training individualization within team sports is required given the position-specific running performance, interindividual training responses, and positional physiological demands of match play. Previous investigations

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have (31) examined the adaptive profile of elite field hockey players using a semiindividualized training load approach ($TRIMP_{mod}$). The results of the study provide evidence to the existence of a dose-response relationship between internal load and aerobic fitness variables with relationships established between change in $\dot{V}O_2max$ ($r = 0.80$) and *vOBLA* ($r = 0.71$). These findings were further validated by Manzi et al. (25) and Akubat et al. (3) who reported similar responses when using a fully individualized approach (iTRIMP) within elite-level soccer players. Mean weekly iTRIMP (AU) was correlated with changes in $\dot{V}O_2max$ ($r = 0.77$), velocity at ventilatory threshold ($r = 0.78$), *vOBLA* ($r = 0.64$), and Yo-Yo intermittent recovery (Yo-YoIR1) performance ($r = 0.69$) within a Serie A cohort and with changes in *vLT* ($r = 0.67$) within elite youth soccer players.

Despite the interest in precise profiling of individual responses to training prescription, only 2 studies have been conducted using a fully individualized approach in team sports (3,25) with no research conducted in hurling. The possible relationship between a fully individualized TL approach and specific fitness variables would be of interest for team sport scientific coaching development (25). This is because presently team sport practitioners have numerous methodologies to monitor athlete internal response across the training process. Methods that have been validated against criterion measures include session rating of perceived exertion (23) and HR-based training impulse methods (3,25,26,31). However, the validity of the criterion measures for internal load used to validate the session rating of perceived exertion method in previous studies has been questioned, because it may not best reflect the individualized physiological response to intermittent activity (3,26). Given that the HR– $\dot{V}O_2$ relationship appears to be valid during intermittent exercise (12) the iTRIMP method has potential for use within a team sport environment such as hurling.

Participation in field sports requires a complex interaction of aerobic, anaerobic, technical, and tactical attributes to pursue competitive success during the season (29). The ergonomic model of hurling is training oriented with the temporal sequence of training sessions during the season being the main affecting variable within the model. Moreover, the seasonal volume of match involvement is not proportional to the training involvements of players. However, Banister (5) proposed that the impact that training has on the fitness and fatigue relationship is important he previously theorized that performance at any given time is a result of an athletes' fitness minus any accrued fatigue. The reported high percentage of time spent in training by Gaelic sport players results in these players being submitted to unique training and competitive demands (7). A previous investigation (21) has shown the importance of the individual response within the ergonomic model of TL adaptation. Therefore the current study aims to examine the relationship between internal load and variables of aerobic fitness in male hurling players using a fully individualized TL approach (iTRIMP).

METHODS

Experimental Approach to the Problem

In this study a descriptive quasiexperimental design was used. Specifically, a team of hurling players was followed up during the 2013–14 season (ie, 8 weeks). The players were monitored for iTRIMP during each training session ($n = 990$). Variables of aerobic fitness were also measured, namely, maximal aerobic power ($\dot{V}O_2max$), speed at 2 $mmol \cdot L^{-1}$ blood lactate concentration (S2), speed at 4 $mmol \cdot L^{-1}$ blood lactate concentration (S4), and running economy (RE). Shuttle performance was also observed pre- and postintervention (Yo-YoIR1 and Yo-YoIR2). $\dot{V}O_2max$ has been reported as a valid measure of aerobic capacity in team sport athletes during a single competitive season (17,19). Speeds at selected blood lactate accumulation points have been reported to provide ecological validity within team sport athletes; furthermore, submaximal aerobic fitness has been shown to be sensitive to seasonal generic and specific training interventions (10). Recently, Castanga et al. (10) reported that speed at 2 and 4 $mmol \cdot L^{-1}$ was sensitive to variations in TL in premiership soccer players. Running economy analysis allowed assessment of the oxygen demand at a sustained workload. The ecological validity of RE has been shown recently with RE sensitive to training interventions within team sport athletes (20,28). The Yo-YoIR tests (levels 1 and 2) have shown construct convergent validity in team sports such as soccer (4). Given that the Yo-YoIR tests were assessed as match and high-intensity match performance criterion for the study (ie, specific aerobic shuttle performance), the test was completed by players to evaluate their preparedness to cope with game running performance during the training period (8). The testing procedures took place during the first week and the last week of training during the intervention period. Testing took place at similar time points across a training week (48 hours apart) with a randomized assessment order to avoid testing sequence effects on test outcomes (1). The magnitude of internal load was assessed using the iTRIMP method to guide both training intensity and training recovery. This was completed to ensure that no undue states of nonfunctional overreaching took place across the testing and training period.

Subjects

Twenty (age, 25.5 ± 3.2 years; height, 178.9 ± 3.2 cm; body mass, 78.5 ± 4.5 kg) hurling players volunteered to participate in the current study. All players were part of the same squad, a top division 1 team that had previously won the county championship, with a minimum playing experience of 8 years. The players trained 3 times a week throughout the period with a league match played on the weekends. Training sessions were mainly devoted to technical-tactical skill development with fitness training performed as a single training session during the period. The training time during the observed period was 21% devoted to ball drills and 13% to generic aerobic training with 22% of the training time spent training for technical-tactical skill development and 10% devoted to matches. Mainly anaerobic training (strength and sprint training) accounted for 14% of all the training time. The remaining time (20%) was spent with warm-up routines. Written informed consent was obtained from the players before the commencement of the study and after local institutional ethical research design approval.

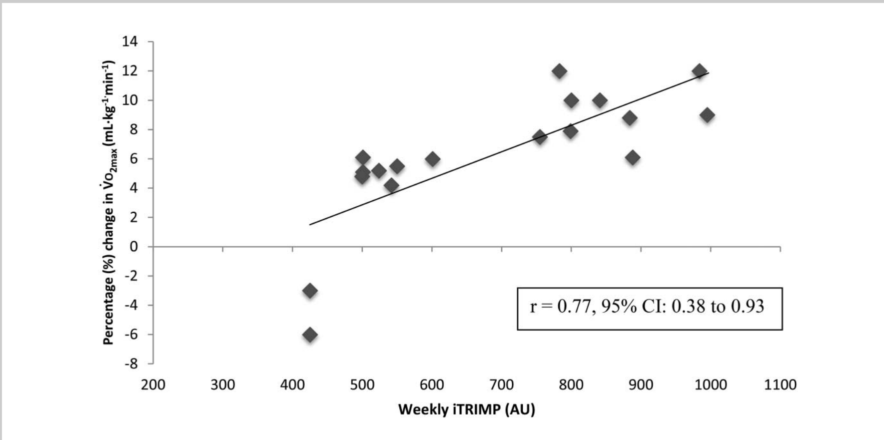

Figure 1. Scatter plot for the relationship between weekly iTRIMP (AU) and percentage improvements in $\dot{V}O_2$max (mL·kg^{-1}·min^{-1}).

Procedures

Players completed a staged incremental test on a motorized treadmill (Cosmed T170; Cosmed, Roma, Italy) for blood lactate concentration profiling, maximal HR, and $\dot{V}O_2$max. The individual lactate profiles were assessed according to the procedures suggested by Akubat et al. (2). During the incremental test each stage was separated by a 1-minute recovery period in which capillary blood lactate (5 μL) was taken (Lactate Plus; Nova Medical, Waltham, MA, USA) in duplicate, with the mean value for each stage recorded. This model of portable lactate analyzer has been shown to provide a valid and accurate measure of capillary blood lactate (16). $\dot{V}O_2$max was recorded as the highest mean $\dot{V}O_2$ obtained for a 1-minute period, with the following criterion met: (a) a plateau in $\dot{V}O_2$ despite increasing treadmill speed, (b) respiratory ratio above 1.10, and (c) attainment of age-predicted HR (24). Heart rate was recorded using HR belts (Polar Team System; Polar Electro, OY, Finland). In addition, RE of players was assessed at 4.47 m·s^{-1} (16 km·h^{-1}) because it is the most commonly used reference velocity for RE (6). The Yo-YoIR1 and Yo-YoIR2 shuttle test was completed following procedures reported by Bangsbo et al. (4). Internal training load (iTRIMP) was assessed for each player training session according to the procedures described by Manzi et al. (25,26). The training volume and intensity were prescribed by the coaching staff during the training period. During all training sessions and tests HR was recorded every 5 seconds with a short range telemetry system (Polar Team System; Polar Electro). The session data were downloaded on a portable personal computer and analyzed using a customized spreadsheet (Excel; Microsoft Corporation, USA).

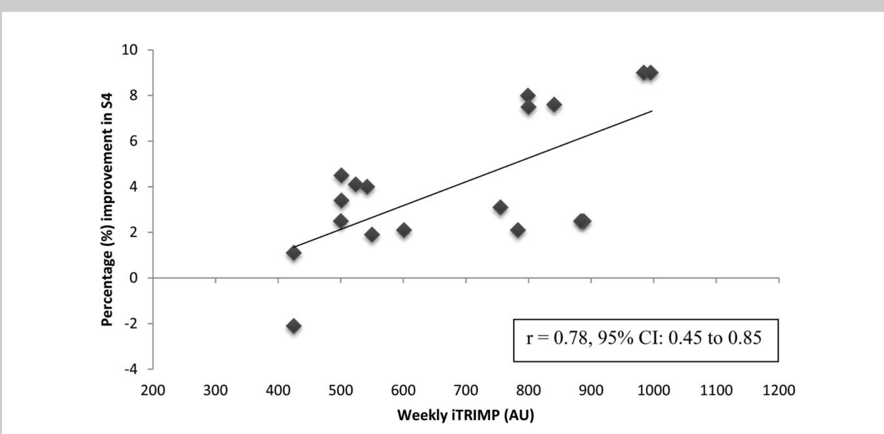

Figure 2. Scatter plot for the relationship between weekly iTRIMP (AU) and percentage improvements in S2 (vLT).

Statistical Analyses

Results are expressed as mean ± *SD* and 95% confidence intervals (CIs). Assumption of normality was verified using the Shapiro-Wilk test. Variables' association was assessed using Pearson's product-moment correlation coefficients. Qualitative interpretations of the correlation coefficients were as defined by Hopkins (18) (0–0.09, trivial; 0.1–0.29, small; 0.3–0.49, moderate; 0.5–0.69, large; 0.7–0.89, very large; 0.9–0.99, nearly perfect; 1 perfect). Changes from before to after the test were examined with paired *t*-tests. Cohen's *d* was used to assess effect size (ES). Effect sizes of <0.2, 0.2–0.6, 0.6–1.2, and 1.2–2.0 were considered trivial, small, moderate, and large, respectively (18). Statistical significance was set at $p \leq 0.05$.

Results

The mean weekly TL for the observed period was of 783 ± 189 AU (95% CI, 590–972 AU). The S2 (8.7 ± 2.0–12.7 ± 1.5 km·h^{-1}; $p = 0.0008$; 95% CI, 0.48–2.52 km·h^{-1}; ES = 1.09), S4 (13.7 ± 2.0–16.7 ± 1.5 km·h^{-1}; $p = 0.0008$; 95% CI, 0.48–2.52 km·h^{-1}; ES = 2.09), $\dot{V}O_{2max}$ (56.7 ± 4.4–63.2 ± 4.1 ml·kg^{-1}·min^{-1}; $p = 0.002$; 95% CI, 0.75–4.3 ml·kg^{-1}·min^{-1}; ES = 1.9), and RE (46.7 ± 5.4–40.2 ± 3.1 ml·kg^{-1}·min^{-1}; $p = 0.002$; 95% CI, 0.75–4.31 ml·kg^{-1}·min^{-1}; ES = 1.9) were significantly improved pretraining to posttraining. Yo-Yo intermittent recovery 1 test performance significantly improved after the training period (1,998 ± 279–2,368 ± 409 m; 95% CI, 237–498 m; ES = 2.1). Similar trends were seen across Yo-YoIR2 performance (1,998 ± 279–2,368 ± 409 m; 95% CI, 237–498 m; ES = 2.1). Individualized training impulse was significantly associated with change in $\dot{V}O_{2max}$ ($r = 0.77$; $p = 0.002$; 95% CI, 0.38–0.93; very large) (Figure 1), S2 ($r = 0.64$; $p = 0.004$; 95% CI, from 0.25 to 0.85; large) (figure 2) S4 ($r = 0.78$; $p = 0.003$; 95% CI, 0.45–0.85; very large); and RE ($r = 0.78$; $p = 0.002$; 95% CI, 0.40–0.93; very large). A large association ($r = 0.69$; $p = 0.009$; 95% CI, 0.45–0.92; large) was found between iTRIMP and change in Yo-YoIR1 and Yo-YoIR2 performance.

Discussion

This study is the first to examine the training adaptations in aerobic intermittent-endurance performance and the association of these adaptations with iTRIMP in male hurling players. The results reported show large to very large associations between weekly iTRIMP (AU) and the percentage changes in the considered aerobic physiological variables. These findings support previous findings in elite premiership soccer players by Manzi et al. (25) who reported similar results; in addition, these findings add support to a fully individualized TL approach having longitudinal validity within team sport players and of an intervention magnitude effect on team sport athletes (3,21). It has been suggested that only methods that show an association with changes in fitness or performance should be considered as measures of load for a particular group of athletes (21,31).

The current study revealed that iTRIMP (AU) had large to very large associations with improvements in fitness variables. Indeed, the interindividual variation in iTRIMP (AU) showed very large associations with the variability in $\dot{V}O_2$max changes. Additionally, improvements in RE and submaximal indices of aerobic fitness showed large to very large associations with weekly iTRIMP, with the results reported being similar to those reported by Manzi et al. (25). The study adds credence to the idea that a fully individualized methodology (iTRIMP) for monitoring TL also allows for successful training prescription. In the study as a reference for match play physical capacity the Yo-YoIR1 and Yo-YoIR2 were used to assess both match-related shuttle performance and high-speed shuttle ability. The results showed significant improvements in Yo-YoIR1 and Yo-YoIR2 test performance assessed. The resulting percentage change of Yo-YoIR1 and Yo-YoIR2 test performance is in line with soccer studies (4,13). Specifically, the magnitude of the changes showed that with fully individualized TL implementation there may be substantial improvement in pre– to post–Yo-YoIR1 and Yo-YoIR2 test performance.

Changes were observed in both S2 and S4 across the training period. Indeed, lactate threshold has previously been found to be a sensitive indicator of changes in fitness in professional team sport players (11). Indeed, Manzi et al. (26) reported significant relationships between iTRIMP and endurance running performance. However, "performance *per se*" in hurling is not as easily determined, because of factors such as skill execution and decision making, which contribute to successful performance. Physical performance in terms of distance covered or distance covered at high speed could potentially be used as it has previously (15), although issues surrounding high match-to-match variability of such measures (15) make meaningful changes difficult to interpret. Therefore, focus on changes across aerobic fitness variables as opposed to match-related outputs of performance may provide more valuable information.

Running economy has been suggested as an often forgotten determinant of physical performance within team sports (28). Running economy has been shown to be an important predictor of endurance performance (6,14) and is a representation of energetic demand for a given running speed (6). Improved RE within team sports is important given the large proportion of time spent in submaximal exercise intensity, therefore improved O_2 cost infers reduced energetic demand (6,14,28). This study is the first to report improvements in RE for a hurling population across a training period. Adaptations in RE were higher than that reported by Owen et al. (28); this may be related to the different baseline fitness levels of the participants in the current study. Interestingly, iTRIMP (AU) was significantly correlated to percentage changes in RE. The current study is the first to report this correlation within intermittent team sport populations; this may be related to the time-consuming and expensive nature of laboratory testing. For example, within some team sport settings the intensive nature of training and competition make time-consuming testing of fitness difficult (2).

Adaptations in aerobic fitness were similar with previous intervention studies in team sport environments (17,25). Specifically, $\dot{V}O_2$max changes of 10.2% are similar to those reported for soccer players over a similar intervention period (13). However, these adaptations must be considered with the timing of both of these studies (preseason vs. in-season). Previously, changes of 6–7% have been reported for $\dot{V}O_2$max across in-season periods for soccer populations (25). The changes observed across submaximal indices of aerobic fitness (7%) matched those reported for soccer players across an intervention period (25). Furthermore, the findings of this study suggest that the magnitude of difference observed for aerobic fitness components may be more sensitive to change over intervention periods (21). Previous studies (25) have reported that to improve maximal aerobic fitness and specific endurance, weekly TL should exceed 500 AU. In doing so, adaptations would be accrued across aerobic fitness and performance. This study has shown similar trends to support these findings with positive adaptations occurring when players had mean weekly iTRIMP values above 500 AU.

The findings of the current study must be considered with regard to a number of limitations. First, the use of blood lactate measures for quantifying the change in aerobic fitness has limitations because the iTRIMP method itself uses blood lactate response to "weight" the intensity of exercise. Therefore, the use of vLT (S2) and vOBLA (S4) might result in pseudocorrelation for adaptation for these variables, which could be accounted for by additional factors such as the initial fitness of the tested cohort. Although other studies (3,25,26,31) have used a similar method, future studies examining the changes in aerobic fitness should consider this limitation. In addition, the duration of the study is a further limitation: although 8 weeks was enough time for significant improvements in fitness, the use of this method across a full season is warranted. Additional limitations have been highlighted by Akubat and Abt (1), who question whether the lactate concentration observed in the blood is a true representation of the overall physiological stress imposed on an athlete. Previously, authors (27) have suggested that exercise intensity and physiological stress increase in a linear fashion similar to the increase observed for blood lactate concentration during exercise; however, this has been questioned by other authors (22).

The significant correlations between iTRIMP and aerobic fitness measures in the current study have shown that only a certain proportion of the improvement in aerobic fitness adaptation can be explained by the iTRIMP variation. This would suggest that other training factors may have affected the improvements observed (25,26). This is not surprising, given the intermittent nature of hurling and the incorporated use of aerobic and anaerobic energy during training and match play. Therefore the modeling of the individual dose-response relationship in hurling with methods previously used in endurance sports (9) appears to be a logical progression. However, this method may not best reflect the intermittent nature of the exercise in team sports. Therefore, future research should assess the validity of the iTRIMP for intermittent team sports.

Practical Applications

The study showed that improvements in aerobic fitness and shuttle performance were associated with individual training responses (iTRIMP) during an 8-week intervention period for hurling players. This demonstrates the responsiveness of the iTRIMP in tracking changes in aerobic fitness and further validates previous findings with the team sport literature (3,25). From the practical point of view, weekly TL in the range of 590–972 AU may ensure a global development of aerobic fitness and performance variables within a hurling specific cohort. This information has a practical impact on training prescription in hurling training with practitioners now having threshold information as to how best to plan weekly internal TLs. Furthermore, the knowledge of threshold values allows for the identification of practical guidelines and helps to develop practitioner understanding as to best practice within the structured ergonomic model of hurling. Given the relationship between iTRIMP method and improvements in aerobic measures of fitness, this measure can be used during the training process to allow practitioners guide performance maintenance and improvements during the competitive hurling season. Practitioners must consider that the use of HR monitors, calculation of iTRIMP, and monitoring of TL do require expertise that needs to be resourced, and these issues should be kept in mind if teams wish to implement the findings of the current study.

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